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THE

METAL WORKER'S HANDY-BOOK

OF

RECEIPTS AND PROCESSES.

BEING A COLLECTION OF CHEMICAL FORMULAS AND PRACTICAL MANIPULATIONS FOR THE WORKING OF ALL THE METALS AND ALLOYS; INCLUDING THE DECORATION AND BEAUTIFYING OF ARTICLES MANUFACTURED THEREFROM, AS WELL AS THEIR PRESERVATION.

EDITED, FROM VARIOUS SOURCES, BY

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EDITOR OF "THE TECHNO-CHEMICAL RECEIPT BOOK" AND "THE METALLIC ALLOYS."

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PREFACE.

SINCE chemistry has become the hand-maid of the industries, it is next to impossible to keep secret for any length of time the composition of a specialty, the analytical chemist taking care that it soon becomes common property. But the results of his labors being of necessity scattered through the various technical journals, not always readily accessible, the advantages derived therefrom by the practical workman are very problematical, unless he can procure the information wanted without the expense of the time and labor required for examining the very numerous original sources of such information.

To collect such flotsam and jetsam of the technical journals, domestic and foreign, has been the design in preparing the matter for the present volume; and thus to furnish to the metal-worker, in the form of a handy-book, receipts and processes of practical application, which would otherwise be in great measure overlooked or entirely lost. In the treatment of the different subjects they have, as far as practicable, been divested of all mere technicalities, also omitting that which was not properly relevant.

At the present time the public is accustomed to the consideration of useful facts, set forth in the briefest terms, and, bearing this in mind, in many cases a single article has been made to embrace data from a number of different sources. With the aid of a liberal supply of foreign and domestic books and journals bearing on the

various subjects, which have been furnished by the enterprising publishers, the editor trusts that not much of interest or importance has been omitted. In consulting innumerable volumes and journals every care has been taken to select the best receipts and processes, and the editor is confident that every metal-worker, no matter in what branch of the industry he may be engaged, will here find something of use and benefit to himself.

In regard to the practical application of the receipts, the observance of the following rules is recommended: 1. Be careful to use the exact proportions prescribed. 2. Always first experiment with small quantities. 3. Should the first attempt prove unsuccessful, do not condemn the receipt, but make another trial, as the fault can generally be traced to a mistake in the manipulation or an error in the quantities.

The alphabetical arrangement of related subjects adopted and a very copious table of contents, as well as index, will render reference to any subject or special receipt prompt and easy.

WM. T. BRANNT.

PHILADELPHIA, *September* 10, 1890.

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THE
METAL WORKER'S HANDY-BOOK
OF
RECEIPTS AND PROCESSES.

I.

CHEMICAL RELATIONS OF THE METALS.

THE chemist distinguishes 49 different metals, and understands under the term "metals" simple bodies (elements) which form certain combinations with oxygen, differing essentially from the combinations with oxygen of the non-metals.

The practical metal worker makes use only of a small portion of the metals; he works up by themselves: *iron*, *copper*, *zinc*, *tin*, *lead*, *silver*, *gold*, *platinum*, *aluminium* and *nickel*. In combination with other metals, *i. e.*, as alloys, are used: *antimony*, *bismuth*, *cadmium*, *manganese*, *tungsten*, *chromium*, *arsenic* and *iridium*.

Although in working metals their physical properties chiefly come into consideration, and the practical metal worker has principally to deal with their fusibility, ductility and divisibility, he must not be ignorant of their chemical properties, because, on the one hand, the gaining of metals is based upon chemical processes, and, on the other, cases frequently occur in practice, especially in processes relating to the ornamentation of the finished article, which can be explained only by a knowledge of chemistry.

For this reason it is considered necessary to devote some space to the chemistry of metals and their behavior towards some non-metallic bodies. The experiments here given, the execution of

which by the reader is urgently advised, may at the same time serve as a preparatory course for the qualitative analysis of metals and alloys given in Section III.

Behavior of Metals towards Oxygen.—Freshly-fractured surfaces of metals exhibit a characteristic lustre—metallic lustre—which remains constant with a few metals only, whilst with others it can be preserved only by certain agents (polish, lacquer). Without such agents the lustre is soon lost in consequence of the action of the air, heat or moisture.

This alteration is most plainly illustrated by potassium. *Potassium* is a metal of such softness that it can be cut with a knife with greater ease than lead. The freshly-cut surface has a silver-like lustre which, however, instantly tarnishes on exposure to air, and the metal is converted into a white body which readily dissolves in water. For this reason potassium by itself cannot be used for technical purposes, and, for reasons to be explained later on, it can only be preserved by keeping it in a sealed tube free from oxygen or beneath the surface of naphtha.

The white body mentioned above has a larger volume and greater weight than the potassium used; consequently the metal must have combined with other bodies, such as occur in the atmosphere. And such is actually the case, one constituent of the air—oxygen—having combined with the metal. The body formed —potassium oxide—having further absorbed water from the air, *potassium hydrate* is formed.

The union of potassium with oxygen is still more rapidly effected by throwing a piece the size of a pea upon water. Its specific gravity being only 0.865, it swims upon the surface. The water, however, is instantly decomposed, hydrogen being rapidly disengaged; and the heat evolved is sufficient to inflame the gas, which burns with a violet flame from the volatilization of a portion of the potassium. In this case oxygen is withdrawn from the water. The potassium hydrate also formed in this experiment has instantly dissolved in the water. To prove that the water actually contains in solution the combination of a metal with oxide—a *metallic oxide*—it is only necessary to dip a piece of red litmus

paper into the water. In pure water the litmus paper is not changed; however, in water containing a metallic oxide in solution, it is colored blue as far as dipped in.

The process of the absorption of oxygen just described is called *oxidation*, the combination of the metal with oxygen, an *oxide*, and, in case the oxide has further absorbed water, this new combination is termed an *hydroxide*.

The oxidation of metals takes place with special ease under the influence of heat. A piece of magnesium wire held in a spirit flame burns with a bright white light, the product of combustion being *magnesium monoxide* or *magnesia*.

Zinc is a readily fusible metal, it becoming liquid at 773° F. By heating it to 932° F. its affinity for oxygen becomes so apparent that on pouring it from the crucible it burns with a splendid greenish light and when cool forms a white flaky body—*zinc oxide*.

Hence the *combustion* of metals is nothing else but their union with oxygen—an oxidation. However the oxidation effected by heat is not always a visible phenomenon of combustion.

By heating a piece of copper-sheet over an alcohol flame the latter becomes green, this being an indication of the combustion of the copper; moreover, the color of the copper also changes, it becoming gradually yellow, violet and blue and finally black. The black body formed is *cupric oxide*. By immersing the sheet after the formation of the oxide in water, the oxide scales off and the sheet shows a brown-red appearance different from that of metallic copper. This brown-red layer can be readily removed by mechanical means (scraping, polishing), but by repeated heating is also converted into oxide. Hence it is also a combination of copper with oxygen, but it contains only half as much oxygen as cupric oxide, and is called *cuprous oxide*.

Cupric oxide contains 63.5 parts of copper to 16 of oxygen, whilst cuprous oxide contains 127 parts of copper to 16 of oxygen.

Most metals unite with oxygen in two proportions; some, however, for instance, lead and manganese, will combine with more oxygen than is contained in their oxides. Such higher grades of oxidation are termed *super-oxides*, whilst the terms *protoxide* and

suboxide are applied to combinations of oxygen containing less oxygen than the oxides.

Platinum, gold, silver and mercury do not combine with oxygen in the manner above described. They retain their metallic lustre, and their oxides can only be prepared with difficulty. To distinguish them from the more readily oxidizable *base* metals they are called *noble* metals.

Combinations of the Metals with Chlorine.—To prepare chlorine for experiments it may be separated from hydrochloric acid, a combination of chlorine and hydrogen. For this purpose pour over 20 parts by weight of finely pulverized pyrolusite (peroxide of manganese) in a flask, 60 parts by weight of hydrochloric acid, and apply a gentle heat; a heavy yellow gas is disengaged which is the substance in question. The reaction consists in an interchange between the two atoms of oxygen of the pyrolusite and four atoms of chlorine from the hydrochloric acid, the oxygen uniting with the hydrogen to form water, while of the chlorine one-half unites with the manganese, forming a chloride, and the other half is given off as gas.

The disengaged chlorine being very poisonous if inhaled, great care must be exercised in its preparation. As a precautionary measure frequently wave a cloth moistened with a few drops of spirit of wine and spirit of sal-ammoniac through the air. The chlorine contained in the air combines with the spirit of sal-ammoniac to a body which is not injurious to the respiratory organs.

To collect the chlorine in a bottle fill the latter with lukewarm water and fasten a bent glass-tube to the boiling flask by means of a perforated tube, allowing the free end of the tube to dip in a dish filled with water. The chlorine escapes in bubbles from the aperture in the tube. To collect it close the bottle filled with lukewarm water with the thumb or a moistened glass-plate and immerse it, mouth down, in the dish filled with water. On removing the thumb or the glass-plate the water does not run out, and the filled bottle can be readily brought over the discharge-aperture of the glass-tube. The escaping chlorine gradually displaces the water.

When all the water is displaced and the bottle filled with chlorine, it is taken out after having previously been corked under water. Powdered *antimony*, if allowed to fall into a bottle filled with chlorine, burns with a white smoke and the appearance of a fiery rain.

A piece of *Dutch gold* (metal-leaf) also burns with a lively flame in chlorine, the product of combustion dissolving with a blue-green color in water.

Genuine gold dissolves in chlorine water, the solution being of a slightly yellowish color. Hence chlorine furnishes a sure means of distinguishing genuine from spurious gold.

The combinations of chlorine with metals are called *metallic chlorides.* Metallic chlorides in solutions are obtained by introducing metals or metallic oxides into hydrochloric acid, iron and zinc being especially soluble in the acid. If, for instance, small pieces of zinc are brought into a bottle provided with two mouths (Fig. 1), and hydrochloric acid diluted with water be poured through a funnel placed air-tight upon the bottle, the zinc is dissolved with a vigorous development of gas. To more closely examine the evolved gas, secure to the other mouth of the bottle a bent glass tube, the free end of which is drawn out to a fine point.

The gas escaping at *a* readily ignites. The flame does not emit light, but gives out such an intense heat that iron wire may be fused in it and platinum wire brought to a red heat. The ignition of the gas, however, must not be effected too quickly, because so long as the atmospheric air is not completely removed from the bottle and the tube, a mixture is formed which ignites with violent detonation by being brought in contact with a lighted match or a red hot wire. The gas evolved is called *hydrogen* and the mixture of hydrogen and air, *oxyhydrogen gas.* By inverting a glass bell (Fig. 1) over the hydrogen flame the aqueous vapors formed condense and run down, drop by drop, on the sides of the glass-bell.

In order to obtain a clear idea of the above-described process of the development of hydrogen, it must be remembered that hydrochloric acid consists of chlorine and hydrogen. Chlorine, however, has a stronger affinity for zinc than for hydrogen, and,

therefore, by bringing zinc into hydrochloric acid, the chlorine leaves its associate, which escapes, while the chlorine forms with

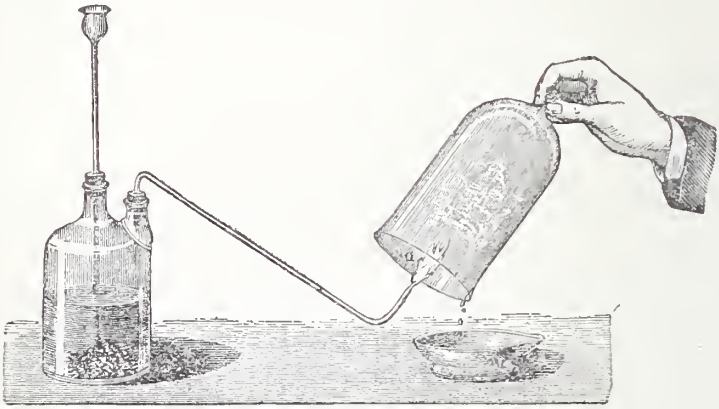


Fig. 1.

the zinc a combination soluble in water—*chloride of zinc*. In dissolving *metallic oxides* in hydrochloric acid *no* hydrogen is liberated, because the hydrogen separating from the acid instantly combines with the oxygen of the oxide to water. Thus, for instance, by bringing cupric oxide into hydrochloric acid a green solution results from which, by evaporation, the chloride of copper is obtained in green crystals. A development of hydrogen does not take place, because:

Cupric oxide	=	copper	+ oxygen.
Hydrochloric acid	=	chlorine	+ hydrogen.
Products:		chloride of copper	+ water.

Gold, platinum and mercury do not dissolve in hydrochloric acid. However, it has previously been stated that gold dissolves in pure chlorine. If, now, hydrochloric acid is to be used for the solution of gold, a body has to be added to the acid which withdraws from it the hydrogen and liberates the chlorine. Nitric acid, being very rich in oxygen, answers this purpose. By carefully

mixing 2 parts by weight of hydrochloric acid and 1 part by weight of nitric acid a mixture known as *aqua regia* is obtained. By placing gold or platinum in this mixture a portion of the oxygen of the nitric acid combines with the hydrogen of the hydrochloric acid to water, whilst the chlorine of the hydrochloric acid combines with the metal to *chloride of gold* or *chloride of platinum.* The nitric acid, deprived of a portion of its oxygen, becomes nitrous gas and nitrous acid, both of which escape as yellow vapors, very injurious to the respiratory organs.

The combinations of silver and lead with chlorine are insoluble in water. Hence hydrochloric acid does not dissolve these metals, a superficial layer of *chloride of silver* or *chloride of lead* being formed, which prevents the further action of the acid.

Combinations of the Metals with Sulphur.—Sulphur is a non-metallic body of yellow color, which melts at 222° F. and boils at 784° F., whereby it is converted into brown-red vapors which, when sufficiently cooled, condense to a yellow powder (flowers of sulphur). Sulphur is frequently associated with metals, a large portion of the latter being gained from metallic sulphides.

By holding a piece of sheet copper in the brown-red vapor of sulphur it loses its flexibility and red color; it becomes brittle and gray; it has lost 25 per cent. of weight and has been converted into *cuprous sulphide*, which consists of 16 parts sulphur and 63.4 parts copper. (There is also a combination of copper with sulphur which contains about 33⅓ per cent. of sulphur.)

By wrapping in a piece of tin-foil one-half of its weight of sulphur and heating them in a test tube over a spirit flame, a portion of the sulphur evaporates, while another portion combines with the tin to brown-black sulphide of tin, which consists of 32 parts sulphur and 118 parts tin. The preparation of the combination of sulphur with tin known as *mosaic gold* (59 parts tin, 32 sulphur) will be given later on.

With *iron* sulphur combines without the assistance of heat. By mixing 30 parts by weight of iron filings, 20 of flowers of sulphur and 20 of water in a small pot and placing the mixture in a warm place in order to allow the water to evaporate, a black powder will

be found in the pot; this powder is *ferrous* sulphide and contains 32 parts sulphur to 56 parts iron.

A combination containing 56 parts iron and 64 parts sulphur occurs naturally and is known as *iron-pyrites*.

Metallic sulphides are mostly distinguished by a characteristic coloration, those known as "pyrites" especially having a beautiful gold lustre.

Laws of Combination of the Elements.—In the preceding paragraphs the phenomena have been explained by which from two simple bodies a new body with new properties may be formed. In the following the opposite case will be considered, because many of the bodies thus formed can be again decomposed into their constituents. The bodies which cannot be further decomposed either by chemical or mechanical means are called *elements*.

TABLE OF THE MOST IMPORTANT ELEMENTS, WITH THEIR SYMBOLS AND ATOMIC WEIGHTS:

Name.	Symbol.	Atomic weight.	Name.	Symbol.	Atomic weight.
ALUMINIUM	Al	27.4	MANGANESE	Mn	55
ANTIMONY (Stibium)	Sb	122	MERCURY (Hydrargyrum)	Hg	200
Arsenic	As	75	NICKEL	Ni	58.8
BARIUM	Ba	137	Nitrogen	N	14
BISMUTH	Bi	210	Oxygen	O	16
Boron	B	11	PALLADIUM	Pd	106.6
Bromine	Br	80	Phosphorus	P	31
CADMIUM	Cd	112	PLATINUM	Pt	197.4
CALCIUM	Ca	40	POTASSIUM (Kalium)	K	39.1
Carbon	C	12	Selenium	Se	79.4
Chlorine	Cl	35.5	Silicium	Si	28
COBALT	Co	58.8	SILVER (Argentum)	Ag	108
COPPER (Cuprum)	Cu	63.4	SODIUM (Natrium)	Na	23
Fluorine	F	19	Sulphur	S	32
GOLD (Aurum)	Au	197	THALLIUM	Tl	204
Hydrogen	H	1	TIN (Stannum)	Sn	118
Iodine	I	127	TITANIUM	Ti	50
IRIDIUM	Ir	198	TUNGSTEN or WOLFRAM	W	184
IRON (Ferrum)	Fe	56	URANIUM	U	240
LEAD (Plumbum)	Pb	207	ZINC	Zn	65.2
MAGNESIUM	Mg	24			

The names of the most important elements are given in the foregoing table. Opposite to them in the third column are placed certain numbers which express the proportions in which they combine together or simple multiples of those proportions; these numbers are called *atomic* or *indivisible weights.* In the second column are placed symbols by which these weights are denoted; these symbols are formed of the first letters of the Latin names of the elements, a second letter being added when the names of two or more elements begin with the same letter. The names of the metallic elements are distinguished by large type.

From the table it will be seen that, for instance, 118 parts of tin combine with 32 parts of sulphur, or with 16 parts of oxygen. The elements combine, however, not only according to the proportion of their atomic weights, but also according to the multiples thereof. On p. 39 was mentioned a combination of tin and sulphur, consisting of 118 parts tin and ($2 \times 32 =$) 64 parts of sulphur, and tin-stone contains for 118 parts of tin ($2 \times 16 =$) 32 parts of oxygen.

As previously stated, each chemical element is denoted, for brevity's sake, by a symbol, which also expresses the atomic weight. Hg, for instance, does not only mean mercury, but also 200 parts by weight of mercury. To express chemical combinations, the symbols of the elements are placed along-side each other, thus:

Hg S = (mercury and sulphur =) *cinnabar.*
Cl H = (chlorine and hydrogen =) hydrochloric acid.

If in the combination one of the elements is contained as a multiple, a small figure denoting the multiple is placed at the right of the symbol. Thus the symbol

For Ferric chloride is $FeCl_2$
" Minium " Pb_3O_4
" Cuprous oxide " Cu_2O
" Nitric acid " HNO_3

Metallic Salts.—As previously mentioned the combinations of the metals with oxygen differ essentially from those of the non-

metals with oxygen. While the first, when soluble in water, have an alkaline taste, the latter have an acid taste; the first are called *bases* and the latter *acids*.

Blue litmus-tincture is an infallible reagent for acids; a drop of it brought into an acid fluid *is colored red*. The tincture is prepared by pouring over commercial litmus ten times its weight of water and letting it stand for 12 hours. The fluid is then decanted from the sediment and kept for use in a wide-mouthed, *open* bottle. In a corked bottle it soon decomposes.

To make litmus-tincture available for the detection of alkalies, compound it drop by drop with dilute hydrochloric acid until it becomes *red*. *Red litmus-tincture is colored blue by an alkaline fluid.*

For many purposes it is of advantage to use litmus-paper in place of the tincture, the fluids to be tested not being colored by it. It is prepared by soaking filtering paper in litmus-tincture, drying and cutting it into small pieces; one-half of each piece is finally drawn through dilute hydrochloric acid, the red portion serving as a reagent for alkalies, and the blue for acids.

In the same manner as the elements combine together the bases may also enter into combinations with the acids. Such combinations are called *salts* and are generally distinguished by the appearance of characteristic crystalline forms.

By dissolving black oxide of copper in hydrochloric acid a blue solution is obtained from which a blue salt crystallizes out. This salt is *cupric sulphate* or *blue vitriol*.

Litharge dissolved in acetic acid gives *acetate of lead* or *sugar of lead*, which crystallizes out in transparent colorless crystals.

By treating metals with acids, salts are also formed, but the metals must first be oxidized before being brought in contact with the acid. By pouring, for instance, dilute sulphuric acid over zinc, the latter withdraws the oxygen from the water while the hydrogen escapes. In dissolving silver in nitric acid the silver withdraws from the acid a portion of its oxygen and the acid becomes nitrous oxide, which on coming in contact with the air is converted into nitrous acid. The same phenomena appear in dissolving copper as well as other metals in nitric acid.

Metallic oxides being thus formed they may combine with the respective acids, the result being sulphate of zinc, or nitrate of silver, or nitrate of copper. It will, however, readily be seen that the gaining of nitrates directly from the metals cannot be profitable, since a portion of the acid is consumed for the oxidation of the metal.

By treating metals with hydrochloric acid metallic chlorides are formed (see page 36). In the metallic chlorides the acid, however, is not combined with a base, though generally they have the character of a salt. To distinguish them and the combinations of the metals with iodine and bromine from the combinations with oxygen, the term *haloid salts* is applied to them.

All the salts mentioned thus far are soluble in water; insoluble in water or soluble with difficulty are, for instance, the salts of barium, strontium, calcium and lead obtained with sulphuric, chromic and sulphurous acids and the haloid salts of lead, silver, etc.

These salts may be obtained by two different methods: either by compounding a soluble salt with the respective acid or by mixing the solutions of two salts which reciprocally exchange their constituents.

By compounding a solution of sugar of lead with tartaric acid tartrate of lead is precipitated, whilst the supernatant liquid contains acetic acid. By adding hydrochloric acid to a solution of nitrate of silver, chloride of silver is precipitated, the supernatant fluid containing nitric acid. If the solution of nitrate of silver be compounded with sodium chloride (common salt) chloride of silver is also precipitated, but the nitric acid liberated from the nitrate of silver combines with the sodium to a salt.

From a solution of sugar of lead compounded with a solution of potassium bichromate, *chromate of lead*, the *chrome-yellow* of the painter, is separated, the acetic acid of the sugar of lead being replaced by the chromic acid of the potassium bichromate. In a similar manner metallic sulphides can be precipitated from the solutions of metallic salts, sulphuretted hydrogen being used for the purpose.

Precipitates with Sulphuretted Hydrogen.—For the preparation of

sulphuretted hydrogen the apparatus shown in Fig. 2 may be used. It consists of the developing vessel *a*, a porcelain sieve *b*, suspended by means of a platinum wire to a glass rod, a funnel *c* and a bent tube, to which is secured a second tube by means of a rubber hose. By the clip *d* the gas developed in the glass vessel may be shut off. The porcelain sieve is filled with small pieces of iron monosulphide and dilute sulphuric acid (1 part acid to 5 water) poured in through the funnel until a copious disengagement of gas takes place. Sulphuretted hydrogen is a colorless gas having the

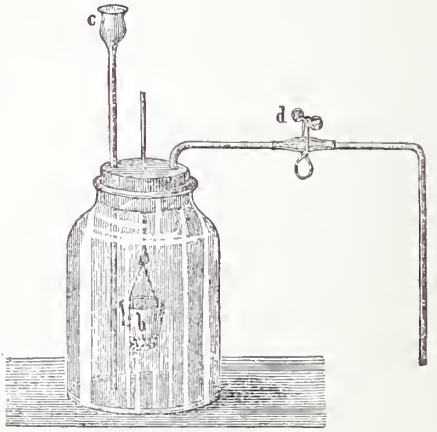


Fig. 2.

odor of putrid eggs; it is not an irritant, but, on the contrary, powerfully narcotic. Water absorbs it with avidity. It has the property of decomposing the oxides of heavy metals and precipitating the metals as metallic sulphides. The precipitate has generally a characteristic color. In the presence of antimony it is orange; of cadmium, arsenic or stannic oxide, yellow; of bismuth or stannous oxide, brown; of gold, brown-black; of silver, lead or gold, black.

If zinc, nickel, iron or cobalt be present in the solution, the latter must first be made alkaline, the combinations of these metals with sulphur being soluble in dilute acids. To make the solutions

alkaline compound them with ammonia until red litmus paper becomes blue. From the alkaline solution sulphuretted hydrogen precipitates zinc with a white color, manganese with a flesh color, and iron, nickel and cobalt with a black color.

II.

THE MOST IMPORTANT METALLIC PREPARATIONS, AND THE CHEMICALS USED IN THE METAL-INDUSTRY.

1. Iron Preparations.

Ferrous sulphate (*copperas, green vitriol*) is obtained in pale green crystals which rapidly oxidize in the air. It is best prepared by dissolving iron filings in dilute sulphuric acid and filtering the boiling hot solution. By mixing the filtrate with spirit of wine the ferrous sulphate separates as a fine white crystalline meal which is washed with spirit of wine and quickly dried between blotting-paper. Ferrous sulphate thus prepared is distinguished by great durability, whilst the commercial article, which is mostly prepared from iron pyrites, quickly oxidizes in the air and gives turbid solutions.

Ammonio-ferrous sulphate is formed by dissolving separately in as little water as possible, 139 parts of ferrous sulphate and 60 of ammonium sulphate, and pouring the solutions heated to 140° F. into a porcelain dish, adding a few drops of sulphuric acid and stirring until cool. A pale blue crystalline meal is deposited which the next day is dried in a funnel, the tube of which is closed by a tuft of cotton.

Ferrous chloride is obtained by dissolving iron in hydrochloric acid. By sufficiently evaporating the solution pale green crystals are obtained which readily oxidize in the air and dissolve with ease in spirit of wine.

Ferric chloride is obtained as a black-brown hygroscopic mass by adding chlorine water to a solution of ferrous chloride, or by

dissolving ferric oxide in hydrochloric acid. In water it dissolves to a yellow fluid.

Sesquioxide of iron, colcothar or *rouge* occurs in commerce as a brown-red powder. It is obtained as a by-product in the manufacture of sulphuric acid from solution of ferrous sulphate. A product of a red-brown color consisting of sesquioxide of iron and clay has recently been brought into commerce under the name of *iron minium*; it is used in the preparation of paint.

Potassium ferrocyanide (*yellow prussiate of potash*) is a commercial article. It occurs in the shape of fine yellow and semi-translucent crystals with mother-of-pearl lustre, which break gradually and without noise. The fracture is jagged, and filled with a multitude of small bright spots.

Potassium ferricyanide (*red prussiate of potash*) is obtained by allowing chlorine to act upon a solution of yellow prussiate of potash. It forms prismatic or sometimes tabular crystals. It serves for distinguishing ferric from ferrous oxides, its solution yielding a deep blue precipitate with ferrous oxides, but not with ferric oxides.

Ferric sulphate is obtained by heating 5 parts of ferrous sulphate with 15 parts of water and 1 part of sulphuric acid, and adding to the boiling solution nitric acid in small quantities until the, at first black, fluid has acquired a brown-yellow color. By evaporation it yields a pale yellow crystalline mass, from which anhydrous ferric sulphate is obtained by compounding the concentrated solution with sulphuric acid. With yellow prussiate of potash ferric sulphate gives a deep blue precipitate which is know as *Berlin blue.* By mixing solution of ferrous sulphate with solution of yellow prussiate of potash a pale blue precipitate—protocyanide of iron—is obtained, which after long standing in the air is also converted into Berlin blue.

2. Preparations of Cobalt and Nickel.

Cobaltous chloride is obtained in blue crystalline scales of a greasy touch by heating the metal in chlorine, or by adding strong hydrochloric acid to a solution of the protoxide in hydrochloric

acid. By absorption of water the color of the scales changes to red.

Cobaltous nitrate is a red crystalline salt and very deliquescent. By prolonged heating the acid escapes and steel-blue sesquioxide of cobalt remains behind.

Cobaltous oxide is a greenish-gray powder readily reduced to the metallic state by ignition in hydrogen, and is converted into the sesquioxide in presence of oxygen.

Nickel chloride is best obtained by dissolving metallic nickel in aqua regia. A solution of nickel or its oxide in hydrochloric acid also yields, after evaporation, nickel chloride in small granular crystals of a blue color, which dissolve in water with a green, and in ammonia, with a blue color. In the dry way it is obtained in delicate, lardaceous scales by conducting chlorine gas over slightly heated metallic nickel.

Nickel sulphate is obtained by dissolving metallic nickel in sulphuric acid compounded with a few drops of nitric acid to accelerate the action. It crystallizes out in emerald-green crystals which readily dissolve in water, and with spirit of sal-ammoniac, give a dark blue fluid.

Nickel nitrate is an emerald-green powder, also soluble in ammonia; it is very deliquescent. It is obtained by dissolving metallic nickel in nitric acid.

By adding potash or soda to a solution of a nickel salt, *nickel hydrate* is precipitated as a green powder. It is soluble in ammonia, forming a violet solution.

3. Copper Preparations.

Copper-powder used in the preparation of copper amalgam is prepared as follows: Place a strip of sheet-zinc in a saturated solution of blue vitriol mixed with an equal volume of hydrochloric acid. The copper is precipitated as a fine powder which, after decanting the supernatant fluid, is washed first with weak and next with stronger alcohol; it is then quickly dried to prevent oxidation.

Cupric sulphate (*sulphate of copper*, *blue vitriol*) is the best known copper salt. It occurs in blue crystals and dissolves in 4 parts of

cold water. It is obtained by dissolving cupric oxide in sulphuric acid, or on the large scale, by heating scrap or refuse copper with sulphur in a furnace so as to convert it into cuprous sulphide which is then oxidized to cupric sulphate and oxide. The mass is thrown into dilute sulphuric acid and the resulting sulphate crystallizes out from the solution.

Cupro-diammonium sulphate.—By adding ammonia to a solution of cupric sulphate a pale blue precipitate is formed which, by a further addition of ammonia, dissolves to a dark blue fluid. By carefully adding to the fluid double its volume of alcohol the cupro-diammonium sulphate crystallizes out after 24 hours.

Copper nitrate is formed by dissolving the metal or oxide in nitric acid and concentrating the solution in a copper kettle. It forms dark blue, prismatic crystals.

Cupric chloride.—This salt is obtained in long bluish-green needles by dissolving cupric oxide in hydrochloric acid and evaporating the solution. By heating the needles water escapes, then chlorine, while *cuprous chloride* remains behind. On exposure to the sun it acquires a copper color and a metallic lustre. It is also obtained as a brown fluid by heating solution of cupric chloride compounded with hydrochloric acid together with copper. By the addition of water the cuprous chloride precipitates as a white powder.

In a cold solution of sodium hyposulphite cuprous chloride dissolves to a yellow fluid, which does not change at an ordinary temperature, but, when heated, deposits black sulphide of copper. Sulphide of copper with a black color is also precipitated by sulphuretted hydrogen from solutions of copper salts.

Copper carbonate.—On adding a solution of soda to one of cupric sulphate a pale blue precipitate of copper carbonate is formed which after some time becomes green; it is known under the name of *mineral green.*

Acetate of copper occurs in two varieties:

1. The *neutral salt* obtained by dissolving cupric oxide in acetic acid. It is found in the market either in the form of dark green crystals or of a bright green powder—highly poisonous—soluble in

water which becomes green; very soluble in ammonia, forming a solution of an azure-blue color.

2. The *basic salt or verdigris;* it is a powder of a fine turquois bluish-green; it is highly poisonous. It is obtained either from copper and vinegar (German verdigris), or by piling together sheets of copper with the skins of pressed grapes (French verdigris). It is imperfectly soluble in water, and difficult to combine with the sulphites and cyanides, unless previously treated with ammonia. It is often used for adulterating the neutral salt.

Cyanide of copper.—Two salts are called by this name; one improperly so called is the ferrocyanide, a powder of a maroon or Vandyke-brown color, obtained by the precipitation of a soluble copper salt with ferrocyanide of potassium; the other, the cyanide, a dirty white powder with a greenish-yellow tinge resulting from the precipitation of a soluble copper salt by cyanide of potassium. Whatever be its mode of production, it is freely soluble in all the alkaline cyanides.

Cupric and cuprous oxides.—The formation of these oxides has already been discussed on page 35. Cuprous oxide is soluble in ammonia. The ammoniacal copper compound formed is a very strong reducing agent, and serves for the precipitation of silver in the manufacture of silver mirrors.

4. Preparations of Lead, Tin and Bismuth.

Acetate of lead (*sugar of lead*) is a poisonous salt obtained by dissolving litharge in acetic acid and evaporating the solution. It is ordinarily found in the shape of crystalline masses; white; light; very soluble; savor, at first sweetish, then metallic. It yields a turbid solution which becomes clear by the addition of a few drops of acetic acid.

Lead carbonate (*white lead*) is used as a paint; insoluble in water.

Lead chloride is readily obtained by adding hydrochloric acid or a soluble chloride to a solution of a lead salt. It crystallizes in white lustrous needles, sparingly soluble in cold water (1 part in

120), but much more soluble in boiling water and in strong hydrochloric acid.

Lead sulphate is formed as a precipitate insoluble in water by mixing solution of a lead salt and sulphuric acid.

Lead chromate (*chrome yellow*).—This salt is obtained as a brilliant yellow precipitate on mixing solutions of potassium chromate or dichromate with lead nitrate or acetate. On boiling it with lime water, one-half of the acid is withdrawn, and a basic lead chromate of an orange-red color left.

Stannous chloride (*Protochloride of tin, Tin-salt*).—This salt is manufactured in large quantities, and occurs in commerce in the form of small, needle-like crystals. It is greasy to the touch, fuses readily, communicates to the fingers a characteristic odor and has a taste at first saline and then astringent and caustic. It is soluble in water, but is partly precipitated in the state of a white subsalt, which readily dissolves in a slight excess of acid.

Stannous chloride is prepared by dissolving granulated tin (in excess) in hot hydrochloric acid, evaporating the solution to a syrupy consistency and letting it crystallize. When the crystals are heated they first fuse in their water of crystallization, which soon evaporates, carrying off a small portion of hydrochloric acid. The operation is completed when thick white fumes begin to be evolved, which is evidence that the salt itself is beginning to volatilize. The fused chloride of tin thus obtained is preferable for tinning with alkaline baths.

Stannic sulphide may be obtained in golden yellow spangles by passing stannic chloride and sulphuretted hydrogen through a heated tube, or by heating mixtures of finely-divided tin, sulphur and sal-ammoniac, or of stannous sulphide and corrosive sublimate. The preparations thus obtained are known under the name of *mosaic gold.*

Bismuth nitrate forms transparent crystals, and is obtained by dissolving bismuth in nitric acid. The crystals are decomposed by water with the production of a basic salt.

5. Preparations of Zinc, Antimony and Arsenic.

Chloride of zinc is obtained in solution by introducing zinc into hydrochloric acid until a portion of it remains undissolved.

Zinc sulphate (white vitriol) is obtained on a large scale by roasting blende and lixiviating the roasted mass with water. In commerce it is found in three forms: either in white or opaque plates, or in large transparent crystals, or in a mass formed of a quantity of needle-like crystals resembling those of tin-salt. Its taste is sour, styptic and metallic, and it is very soluble in water, which remains colorless.

Zinc oxide prepared by burning the metal is employed as a pigment under the name of *zinc white;* it is chiefly valued for its permanency, as it is not blackened by exposure to sulphuretted hydrogen like white lead.

Iron black is finely divided antimony powder precipitated from a solution of antimony by zinc. It imparts to figures of plaster of Paris and papier-maché the appearance of bright steel; hence its name.

Antimony trichloride is obtained by the action of chlorine or mercuric chloride upon the metal or by heating the trisulphide with mercuric chloride. It is a translucent, light yellow fatty mass, whence its common name of *butter of antimony.* On exposure to the air it absorbs water with avidity, forming a very caustic fuming liquid. An addition of water causes turbidity and precipitation; hence it is diluted with alcohol.

Tartar emetic.—By boiling the tetroxide of antimony with cream of tartar it is dissolved and the solution yields on evaporation crystals of tartar emetic, which is almost the only antimonious salt which will bear admixture with water without decomposition. In the metal industry it is used for the production of lustrous colors upon brass.

White arsenic or *arsenious acid,* a very poisonous substance, which generally occurs in the shape of a white powder and sometimes in vitreous-like lumps resembling porcelain. It is slightly

soluble in water. It is employed in certain silver-whitening baths and also in the electro-baths for brass.

Schweinfurt green is obtained from equal parts of arsenious acid and neutral verdigris by heating the solutions by themselves and mixing them boiling hot. It consists of 31.29 parts cupric oxide, 58.65 arsenious acid and 10.6 acetic acid. It is very poisonous.

6. Preparations of Mercury and Silver.

Mercurous sulphate is a white, sparingly soluble, crystalline powder, formed by slightly heating mercury with concentrated sulphuric acid.

Mercuric nitrate is obtained by dissolving at a gentle heat mercury in nitric acid and, when solution is complete, boiling the fluid for a few minutes.

Mercurous nitrate is a white crystalline salt, obtained by dissolving the metal in cold dilute nitric acid. Potash solution precipitates from the solution mercurous oxide, which is readily resolved on exposure to light or by simple trituration in a mortar into mercury and mercuric oxide.

Mercuric chloride or *corrosive sublimate* is obtained by dissolving the metal in aqua regia. It crystallizes out in the form of white columns; it is highly poisonous.

Nitrate of silver (*silver nitrate, lunar caustic*) is one of the most important silver salts. It is readily made by dissolving the metal in moderately dilute nitric acid and concentrating the solution when it separates out in anhydrous tables. In the trade the salt is found in three forms: either as crystallized nitrate of silver in thin rhombic and transparent plates; or in amorphous, opaque and white plates of fused nitrate; or in small cylinders of white, or gray, or black color, according to the nature of the mould employed, in which form it constitutes the lunar caustic for surgical uses.

Nitrate of silver dissolves in its own weight of water, forming a neutral solution, which is partially reduced by the action of hydrogen with the production of silver and silver nitrate. In the metal

industry it is employed for preparing silver-baths, metallizing moulds and for many other purposes.

Chloride of silver (*argentic chloride, horn silver*) is readily obtained by adding hydrochloric acid or a chloride to a solution of nitrate of silver. It forms a white curdy mass almost absolutely insoluble in water. On exposure to the light it soon turns blue and then black. To prevent this decomposition it should be kept in blue or opaque bottles. It fuses at a high temperature and acquires the appearance of horn, from which it derives its name of horn silver. It is employed in the preparation of the baths for electro-silvering, for the whitening baths and for the pastes for silvering by friction. It readily dissolves in ammonia.

Argentic oxide is precipitated as a black powder from a solution of nitrate of silver by ammonia. It is redissolved by an excess of the precipitating agent.

Silver carbonate is insoluble in water and is formed as a precipitate on bringing together solutions of nitrate of silver and of potash.

Cyanide of silver (*prussiate or hydrocyanate of silver*).—This substance is white, becomes slowly black when exposed to light and is insoluble in water and in cold acids, which, however, will dissolve it with the aid of heat. It is prepared by passing cyanogen gas through, or adding hydrocyanic acid to, a cold solution of nitrate of silver. The precipitate formed is thoroughly washed and kept in a moist condition in blue or black bottles.

Silver sulphate is formed by the action of hot concentrated sulphuric acid on the metal, or by adding sulphuric acid to a strong solution of silver nitrate. It is sparingly soluble in water; it forms with ammonia a readily soluble compound.

Silver sulphide is obtained by fusing silver with sulphur. It is readily fusible, forming, when cold, a leaden-gray mass, which is so soft that it may be readily cut with a knife and pressed into moulds.

Silver hyposulphite is prepared by adding, to a solution of nitrate of silver, ammonia until the precipitate is dissolved and then pour-

ing in a concentrated solution of sodium hyposulphite and alcohol. The salt separated is washed and dried.

7. Preparations of Gold and Platinum.

Chloride of gold (*auric chloride*) is generally prepared by dissolving finely laminated or otherwise comminuted gold in aqua regia. The operation is conducted in a glass flask and with the aid of a gentle heat until all the gold has dissolved to form a yellow liquid, which still retains a great excess of acid. The heat is then slightly increased and continued until the liquid is a hyacinth-red. After cooling a crystallized mass of a fine yellow color is obtained, which is well adapted to the preparation of the immersion-gilding bath.

On the other hand, for electro-gilding baths, the action of the fire should preferably be continued until the liquid in the flask has acquired a blackish-red color without losing its fluidity. On cooling the crystals are brown-red.

Aurous chloride is a yellowish-white insoluble powder, obtained by heating auric chloride to about 302° F. until the color changes to pure yellow.

Cyanide of gold (*prussiate or hydrocyanate of gold*) is prepared by precipitating a solution of chloride of gold with a solution of cyanide of potassium. An excess of alkaline cyanide must be avoided, as it will dissolve the precipitate and form a double cyanide of gold and potassium. This salt is employed for the preparation of gilding baths and is preferred to the chloride for this purpose, as it avoids the objection of introducing chloride of potassium into the gilding solution.

Gold salt (*Gozzy's gold salt, Sal auri Figuieri, Aurum muriaticum natronatum crystallisatum*).—Dissolve 8 parts of gold in aqua regia. Add 2 parts of common salt and evaporate to dryness. *Or* dissolve 1 part of gold in a mixture of 4 parts of hydrochloric acid and 1 of nitric acid, evaporate the solution to crystallization, dissolve it in 8 parts of water, mix the solution with 0.25 part of common salt and again evaporate to crystallization. In the presence of free acid dissolve the mass in water, evaporate to crystallization and recrystallize several times. *Or,* dissolve 100 parts of

gold in 400 of hydrochloric acid and 100 of nitric acid, heat until all the nitric acid is decomposed, then mix with 73 parts of sodium carbonate and evaporate to dryness. (In place of common salt or sodium carbonate potassium chloride or potassium carbonate may be used.)

Purple of Cassius, so named after its discoverer, is the dark-purple precipitate formed on bringing together dilute solution of chloride of gold with a solution of stannous chloride. Purple of Cassius imparts to pastes and enamels a beautiful purple color; it is prepared as follows: Dissolve 30.86 grains of tin in boiling aqua regia, evaporate the solution at a gentle heat until solid, then dissolve it in distilled water and after adding 30.86 grains of a solution of stannous chloride dilute with 10 quarts of water and stir into the fluid a solution of chloride of gold prepared from 0.75 grain of gold and not containing an excess of acid, which is effected by evaporating the solution of chloride of gold to dryness and heating for some time at 322° F. On adding 1 oz. 12 drachms of ammonia the fluid becomes turbid and the purple separates out.

Platinic chloride (*chloride of platinum, Tetra-chloride of platinum*).—This salt is prepared like the chloride of gold; but the aqua regia should be made of 5 parts of hydrochloric acid to 3 of nitric acid. The product is evaporated nearly to dryness in a porcelain capsule from which it may readily be detached after cooling. If it be desired to have it more acid, and therefore more easy to dissolve, it is poured while still fluid, and not sensibly fuming, upon a porcelain plate, from which it is easily separated after cooling. Platinic chloride is soluble in water and alcohol, caustic soda and sodium carbonate and phosphate; in the latter case it forms double salts like chloride of gold.

Ammonio-chloride of platinum is precipitated from a solution of platinic chloride by mixing it with sal-ammoniac or another ammoniacal salt. It is a lemon-yellow powder soluble with difficulty in water. By heating the powder *spongy platinum* is obtained.

8. Acids.

Sulphuric acid (*oil of vitriol*).—Ordinary sulphuric acid is a colorless, odorless, dense fluid, which is produced in large quantities by oxidizing in lead chambers moist sulphurous acid by the vapors of nitric acid. Its name of oil of vitriol comes from its oily consistency and from the green vitriol (sulphate of iron), from which it was formerly obtained by distillation in closed vessels.

Concentrated sulphuric acid, which may still contain 18.46 per cent. of water, attacks and blackens organic substances, becoming itself more or less dark thereby. The particles of dust flying in the air and falling into it are sufficient to produce this phenomenon. Sulphuric acid is very hygroscopic, *i. e.*, very much inclined to absorb water. On mixing with water it becomes heated to a considerable extent. Now, as it is frequently used in a dilute state, it is necessary to remark that *water should never be poured into the acid;* pour the acid in a thin jet and in small quantities into the water, stirring diligently with a glass rod. To avoid too much heating and the explosion of the mixing vessel place the latter in another vessel filled with water. The acid is preserved in glass bottles closed with glass stoppers. The value of commercial sulphuric acid being dependent on its content of anhydrous acid, it is tested with an acrometer. Beaumé's aerometer sinks in pure concentrated sulphuric acid, specific gravity 1.842 to 66°. The table on p. 57 gives information in regard to the content in other cases; it may be remarked that the sulphuric acid to be tested should be at 59° F.

Anhydrous sulphuric acid is not found in commerce. *Fuming sulphuric acid*, also called *Nordhausen* sulphuric acid, is obtained by burning sulphate of iron, and is a mixture of anhydrous and ordinary sulphuric acid. It is a brownish fluid of a pungent odor (sulphurous acid) which fumes in the air, and on heating yields vapors of anhydrous sulphuric acid. Fuming sulphuric acid is chiefly used for dissolving indigo.

PERCENTAGE OF ANHYDROUS SULPHURIC ACID AT DIFFERENT DEGREES BÉ.

Degrees Bé.	Anhydrous acid.	Hydrated sulphuric acid.	Degrees Bé.	Anhydrous acid.	Hydrated sulphuric acid.	Degrees Bé.	Anhydrous acid.	Hydrated sulphuric acid.
0	0.7	0.9	23	22.1	25.8	46	46.4	56.9
1	1.5	1.9	24	22.1	27.1	47	47.6	58.3
2	2.3	2.8	25	23.2	28.4	48	48.7	59.6
3	3.1	3.8	26	24.2	29.6	49	49.8	61.0
4	3.9	4.8	27	25.3	31.0	50	51.0	62.5
5	4.7	5.8	28	26.3	32.2	51	52.2	64.0
6	5.6	6.8	29	27.3	33.4	52	53.5	65.5
7	6.4	7.8	30	28.3	34.7	53	54.9	67.0
8	7.2	8.8	31	29.4	36.0	54	56.0	68.6
9	8.0	9.8	32	30.5	37.4	55	57.1	70.0
10	8.8	10.8	33	31.7	38.8	56	58.4	71.6
11	9.7	11.9	34	32.8	40.2	57	59.7	73.2
12	10.6	13.0	35	33.9	41.6	58	61.0	74.7
13	11.5	14.1	36	35.1	43.0	59	62.4	76.4
14	12.4	15.2	37	36.2	44.4	60	63.8	78.1
15	13.2	16.2	38	37.2	45.5	61	65.2	79 9
16	14.1	17.3	39	38.3	46.9	62	66.7	81.7
17	15.1	18.5	40	39.5	48.3	63	68.7	84.1
18	16.0	19.6	41	40.7	49.8	64	70.6	86.5
19	17.0	20.8	42	41.8	51.2	65	73.2	89.7
20	18.0	22.2	43	42.9	52.8	66	81.6	100.0
21	19.0	23.3	44	44.1	54.0			
22	20.0	24.5	45	45.2	55.4			

Nitric acid (*aqua fortis*).—It is found in commerce of various colors and degrees of strength but rarely chemically pure. It is a liquid of a nauseous smell; taste, strongly acid. It destroys the skin and the majority of organic matters, dissolves most of the metals, always with a production of orange vapors. It is obtained by decomposing nitrate of soda with sulphuric acid and condensing the vapors formed. Nitric acid may also be diluted with water, the same precautions as given for sulphuric acid being used. The content of anhydrous and hydrated nitric acid in the mixtures is found from the following table:

PERCENTAGE OF ANHYDROUS NITRIC ACID AT DIFFERENT DEGREES BÉ.

Degrees Bé.	Density.	100 parts contain at 32° F.		100 parts contain at 59° F.	
		Anhydrous nitric acid.	Hydrated nitric acid.	Anhydrous nitric acid.	Hydrated nitric acid.
6	1.044	5.7	6.7	6.5	7.6
7	1.052	6.9	8.0	7.7	9.0
9	1.067	8.7	10.2	9.8	11.4
10	1.075	9.8	11.4	10.9	12.7
15	1.116	15.1	17.6	16.6	19.4
20	1.161	20.7	24.2	22.5	26.3
25	1.210	26.9	31.4	28.9	33.8
30	1.261	33.5	39.1	35.6	41.5
35	1.321	41.1	48 0	43.5	50.7
40	1.384	50.0	58.4	52.9	61.7
45	1.454	61.9	72.2	71.1	78.4
46	1.470	65.2	76.1	72.2	83.0
47	1.485	68.7	80.2	74.7	87.1

Hydrochloric acid.—This acid is gaseous, and emits abundant and dense fumes in contact with air. Water at the temperature of 68° F. dissolves 460 times its own volume of this acid; that is, 1 quart of water will dissolve 460 quarts of this gas and the original volume of the water will be increased about one-third. It is this solution of the acid that is found in commerce and always employed in the arts; it is generally contaminated with sulphurous and sulphuric acids, and by perchloride of iron which imparts to it a yellow color. A concentrated solution of hydrochloric acid in contact with moist air emits dense fumes which are the most apparent in the presence of ammoniacal vapors. Hydrochloric acid is mostly obtained as a by-product in the manufacture of soda. The content of gaseous hydrochloric acid in hydrated hydrochloric acid will be seen from the following table:

PERCENTAGE OF GASEOUS HYDROCHLORIC ACID AT DIFFERENT DEGREES BÉ.

Degrees Bé.	100 parts contain gaseous acid.		Degrees Bé.	100 parts contain gaseous acid.		Degrees Bé.	100 parts contain gaseous acid.	
	at 32° F.	at 59° F.		at 32° F.	at 59° F.		at 32° F.	at 59° F.
0	0.0	0.1	9	12.7	13.4	18	27.0	28.4
1	1.4	1.5	10	14.2	15.0	19	28.7	30.2
2	2.7	2.9	11	15.7	16.5	20	30.4	32.0
3	4.2	4.5	12	17.2	18.1	21	32.3	33 9
4	5.5	5.8	13	18.9	19.9	22	34.1	35.7
5	6.9	7.3	14	20.4	21.5	23	36.1	37.9
6	8.4	8.9	15	21.9	23.1	24	38.0	39.8
7	9.9	10.4	16	23.6	24.8	25	40.2	42.4
8	11.4	12.0	17	25.2	26.6			

Aqua regia (*nitro-muriatic acid*) is a mixture of 2 parts hydrochloric acid and 1 nitric acid (see p. 39). But as both acids occur in commerce in different degrees of strength it will be readily seen that the action of aqua regia will not always be equally vigorous. To always obtain aqua regia of an equal strength take

For 100 parts of hydrochloric acid.	Nitric acid of					
	42°	38°	34°	29°	24°	19°
25°	108	126	150	178	218	284
23°	94	108	130	154	190	246
20°	82	96	114	136	168	218
18°	72	84	100	118	146	190
16°	62	72	86	102	126	162
13°	52	60	72	86	106	136

On mixing the two acids they are decomposed in such a manner that two combinations, gaseous at an ordinary temperature, and free chlorine, are formed. It is chiefly due to the content of chlorine gas that aqua regia is the strongest solvent for metals.

Gold and platinum dissolve only in aqua regia, and various metallic sulphides (cinnabar, iron pyrites) are decomposed by it.

Chromic acid is obtained by adding to one measure of a solution of bichromate of potash, saturated at 130° F., one measure and a half of concentrated sulphuric acid and allowing the solution to cool, when chromic acid crystallizes out in fine crimson needles. The needles adhere very firmly to the sides of the vessel, so that the fluid can be readily poured off by inclining the vessel. When this is done the crystals of chromic acid are brought with the aid of a glass rod upon a porous brick which is placed under a glass bell. After 24 hours the water adhering to the crystals has been absorbed by the brick, and the crystals, which are now entirely dry, are preserved in a wide-mouthed bottle.

Solution of chromic acid crystals is a very good etching agent for metals. In modern times it is also frequently used as an excitant in galvanic batteries.

Acetic acid is found in commerce in various degrees of concentration. Pure anhydrous acetic acid is a colorless fluid of a very acid taste and a pungent odor. At 32° F. it solidifies to a crystallized mass (glacial acetic acid), which melts at 59° F. In modern times wood vinegar or pyroligneous acid is employed in large quantities; it is colorless or more or less yellow. It often possesses an empyreumatic odor and generally marks 8° of the hydrometer. Wine vinegar is more or less colored, and may be concentrated. Its smell is sufficient to distinguish it.

Tartaric acid is found in commerce as powder and in crystals. Solutions of it should be prepared immediately before use, as by prolonged standing they easily decompose with the formation of mould.

Boric or boracic acid is much used in nickelling. United with sodium it constitutes borax. In commerce it is found in the shape of scales with nacreous lustre and greasy to the touch. When in vitreous masses, more or less translucent, it is anhydrous and has been subjected to igneous fusion. It is also employed for increasing the whiteness of silver alloys and for decomposing the subsalts deposited in electro-baths containing cyanide of potash.

Oxalic acid (*salt of sorrel*) forms crystals which, when heated on a platinum sheet, fuse and burn without residue. It is very poisonous.

Prussic acid (*hydrocyanic acid*) is one of the most poisonous substances known and should be used very seldom, and then with the greatest care. Diluted prussic acid is colorless, with a bitter taste and the characteristic smell of bitter almonds. It is employed for maintaining the strength of the pyrophosphate of gold in immersion baths and for decomposing the alkaline carbonates formed in baths with cyanide of potassium.

9. Various Chemicals and Substances Used in the Metal Industry.

The following substances used occasionally by the metal worker are arranged in alphabetical order:

Ammonia (*spirits of hartshorn*).—This compound, which generally bears the name of ammoniacal gas when in the gaseous form, and of ammonia when in solution, presents properties similar to those of potash, soda and other alkalies which are metallic oxides. On account of this analogy it is customary to consider it as the oxide of a hypothetical metal, *ammonium*, a compound radical composed of nitrogen and hydrogen. Gaseous ammonia dissolves in water eagerly, one volume absorbing, when cold, about 500 volumes of the gas. Aqua ammonia is a colorless liquid, possessing a characteristic and overpowering pungent smell. Ammonia restores the blue color of litmus reddened by an acid and saturates the affinities of the most powerful acids, and on this account is often employed for removing acid stains upon clothes. The aqua ammonia used in the arts is obtained chiefly from the *ammoniacal liquor* resulting from the destructive distillation of coal for the manufacture of gas.

Ammonium phosphate.—This salt is obtained by the *exact* saturation of phosphoric acid with ammonia. The liquid obtained is then evaporated at a gentle heat, and a few drops of ammonia are now and then added in order to compensate for that removed by

the decomposition of small quantities of the salt. When the liquid becomes syrupy it is set aside to crystallize in a cool place. This salt is used for the composition of baths for thick platinum deposits.

Ammonium sulphide (*sulphydrate, or hydrosulphate of ammonia*) is a liquid and of a deeper color, according as it contains more sulphur. Its smell is exceedingly pungent and offensive, and its taste is alkaline and nauseous. The sides of the bottles in which it is kept are often covered with a pellicle of sulphur or sulphides. By rapid evaporation a residue of sulphur is left. It rapidly forms sulphides with the metals and produces on silver the black coating misnamed oxidation. It is often employed for bronzing, for producing the so-called "patina" on the surface of various metals or alloys. It is prepared by saturating ammonia with sulphuretted hydrogen gas.

Benzine (*benzole, light oil from coal-tar*) is a clear fluid of a characteristic odor; it is very volatile and inflammable. It is an excellent solvent for all the oils, resins, gums, varnishes, fats, etc.

Borax (*sodium biborate*) occurs generally in colorless prismatic crystals, which swell up on heating, and before the blow-pipe form a colorless glass. This glass dissolves nearly all the metallic oxides, and on account of this borax is much used for tests with the blow-pipe, and in hard-soldering. Borax is employed for restoring the shade of defective gildings and for destroying the sub-salts of silver formed in electro-silvering baths and which injuriously affect the color of the electro-silver deposits.

Calcium, potassium and sodium sulphides.—These salts are obtained by boiling the alkali and flowers of sulphur in a certain quantity of water. In commerce they are found in fused brown masses, the potassium sulphide especially being known as *liver of sulphur*. They dissolve in water with a yellow or red color and have the characteristic odor of sulphuretted hydrogen; when treated by an acid they give off sulphuretted hydrogen, yielding at the same time a deposit of sulphur.

Caoutchouc (*India rubber, gum elastic*) is extracted from the sap flowing from incisions made in the trunk of *Ficus elastica* or *cahuca*,

a tree indigenous to Java. When pure it is white, but its color is generally brown or red, caused by the smoke of the fire employed in drying it.

The combination of sulphur with caoutchouc furnishes the product called "*vulcanized rubber*," and by modification of the treatment it may be converted into the substance known as "hard rubber," which is used for a multitude of purposes. Water, alcohol and acid do not dissolve caoutchouc; on the other hand, ethers, bisulphide of carbon, essential oils and benzine dissolve and leave it behind after the volatilization of the solvent.

Carbon bisulphide is a colorless clear fluid of very disagreeable odor. It is extremely volatile, inflammable and burns with a blue flame. Most resins, as well as caoutchouc, gutta-percha, sulphur, and phosphorus are soluble in carbon bisulphide.

Emery.—As regards its chemical composition emery is crystallized alumina (aluminium oxide), the same as the ruby, topaz and sapphire. On account of its hardness it is used for grinding metals and glass, and for this purpose can be had in commerce in various degrees of fineness. Besides, in the shape of powder, it is also used secured to paper or linen by glue (emery-paper, emery-cloth), as well as mixed with shellac, linseed oil and water-glass and pressed into moulds (emery-wheels, emery-files).

Graphite (*plumbago, black lead*).—This is nearly pure carbon and is found in amorphous masses in several countries. It is black, with a metallic lustre and is difficult to ignite. It is employed for imparting electric conductivity to the surfaces of many substances which are not naturally conductors, and also for preventing adherence of two superposed metals.

Gutta-percha is the hardened milky juice of a tree indigenous to the East Indies. It generally occurs in the shape of large thick blocks. It is of a chocolate-brown color, very solid at an ordinary temperature and insoluble in water, acids and alkalies. Carbon bisulphide and chloroform dissolve it in the cold, and oil of turpentine when heated. On heating gutta-percha to from 112° to 140° F. it becomes so soft and plastic that it can be brought into any

desired shape. On cooling it again becomes solid, retaining, however, the acquired shape.

Magnesia (*calcined*) is a white loose powder, consisting of magnesium oxide, and is obtained by calcining carbonate of magnesia. It is slightly soluble in water, and feebly alkaline.

Potassium bicarbonate.—This salt is white and colorless and crystallizes either in tabular form, like nitrate of silver, or in cubes, like common salt. It is soluble in tepid water, without decomposition; but at the boiling point it loses one-fourth of its carbonic acid and becomes a sesquicarbonate. At a red heat it is transformed into simple carbonate, *i. e.*, it loses another fourth of carbonic acid.

Potassium cyanide (*white prussiate of potash*) is a very poisonous, colorless salt, with an odor of prussic acid. The use of potassium cyanide in electro-plating and gilding depends upon the power of the solution of the salt to dissolve the cyanides of gold and silver, forming compounds which are easily decomposed by the galvanic current, with deposition of metallic gold or silver upon any object capable of conducting the current which may be attached to the negative pole. Solution of potassium cyanide is also able to dissolve metallic silver and sulphide of silver, which is taken advantage of in removing photographic stains from the hands and in cleaning silver or gold lace.

Potassium hydroxide (*caustic potash*) is found in commerce in sticks the thickness of a lead-pencil. It is very deliquescent and must be kept in hermetically closed bottles.

Potassium nitrate (*saltpetre*) readily yields a portion of its oxygen to other bodies, and consequently acts in an oxidizing manner upon metals, carbon, etc. It is also used as a flux.

Sodium bicarbonate.—The properties, etc., of this compound correspond with those of potassium bicarbonate.

Sodium hydroxide (*caustic soda*) occurs in commerce in thick white masses. It becomes deliquescent by the absorption of carbonic acid from the air, whereby it is converted into carbonate of soda.

Sodium phosphate (*tribasic phosphate of soda*) is prepared by treating calcined and powdered bones with sulphuric acid and

letting the mixture rest for several days. The acid phosphate of calcium is then removed by washing the residue, and the filtered liquid is saturated with sodium carbonate until carbonic acid is no longer disengaged. The clear liquid is then concentrated until it marks 33° Bé. and is allowed to crystallize once or several times. Sodium phosphate is used for hot electro-gilding baths and other purposes.

Sodium pyrophosphate (*bibasic phosphate of soda*).—The commercial salt is generally in the form of a white powder, odorless, and with a hot, saline, alkaline and then bitter taste. It is soluble in water, but not so freely as the preceding salt.

Sulphur occurs in commerce either in the shape of sticks or of a fine powder (flowers of sulphur). On heating sulphur to 446° F. and suddenly cooling it becomes soft and plastic and may be used for taking impressions of medals, etc. It is not soluble in water, but dissolves in heated oils and bisulphide of carbon. Metallic sulphides dissolve in melted sulphur, a mass known as *Spence's metal* being formed which may be used for casting. The color of Spence's metal is gray, sprinkled with lustrous dots. It has about the hardness of zinc, a specific gravity of 3.37 to 3.7, melts at 320° F., expands on cooling and is claimed to be capable of resisting well the disintegrating action of the atmosphere; it is attacked by but few acids, and by them but slowly; is insoluble in water and may receive a high polish. It makes clean, full castings, taking perfect impressions; it is cheap and easily worked. It is prepared by introducing iron disulphide (FeS_2), zinc blende and galena into melted sulphur. According to an analysis by Jüptner it contains: iron disulphide, 57.38 per cent.; free sulphur, 32.44; zinc sulphide, 3.93; various substances and silicic acid, 5.84; cupric sulphate, a trace.

Tartar (*potassium bitartrate*).—This salt occurs nearly pure in wine, from which it becomes separated in the shape of small white or red crystals, according to the color of the liquor. It is collected from the sides of wine casks and purified by bone-black, in which state it is known as *cream of tartar*. Tartar is acid, slightly sol-

uble in water, and it decrepitates in the fire, where it blackens, disengaging a smell like burnt sugar.

III.

DIRECTIONS FOR THE DETERMINATION OF THE CONSTITUENTS OF METALLIC ALLOYS, IMPURITIES OF THE TECHNICALLY MOST IMPORTANT METALS, ETC.

Since most metals dissolve in nitric acid, pour over the sample in a glass flask chemically pure nitric acid and assist solution by careful heating over a spirit flame.

1. Gold and platinum dissolve only in aqua regia; tin and antimony are only oxidized by nitric acid. Hence if an undissolved residue of the sample remains it indicates *gold*, *platinum* or *antimony* (or carbon with cast-iron). Filter the residue, which may be termed A, from the solution and treat it further as given under 15.

2. Dilute a sample of the filtrate (or, if filtration be not necessary, a sample of the solution) in a test-glass with distilled water. If turbidity or a white precipitate appears it indicates *bismuth*, which has been precipitated as basic salt from the solution by water. The non-appearance of this reaction, however, is not conclusive proof of the absence of bismuth, since an excess of nitric acid prevents the precipitation of basic bismuth nitrate. To be certain, first evaporate the sample to drive off the acid and then dilute with water.

3. Another sample of the solution is mixed with dilute sulphuric acid. If a white, granular precipitate is formed, the sample of metal contains *lead*, because only sulphates of lead are insoluble in acids.

4. If, on mixing a portion of the original solution, or in case the test for lead was successful, a portion of the filtrate free from lead, with pure hydrochloric acid, a white, caseous precipitate is formed if the metallic sample contains *silver* or *mercury*. In case test

No. 3 has not been previously executed, a precipitate of chloride of lead may also take place if *lead* is present. For the further treatment of this precipitate, which may be termed *B*, see under 14.

5. Add to a small sample of the solution in nitric acid a few drops of caustic ammonia. If the solution acquires a fine blue color, the sample of metal contains *copper*.

6. To test for *mercury* evaporate a few drops of the solution in nitric acid to remove the acid and dilute with water. If a copper wire placed in the aqueous solution turns gray and becomes white with a metallic lustre on rubbing with the fingers, the presence of mercury is shown.

7. Next conduct into a somewhat larger sample sulphuretted hydrogen, and compound it with water containing sulphuretted hydrogen. All metals mentioned in 1 to 6 are precipitated as metallic sulphides. Hence a precipitate, which may be termed *C*, will generally be obtained. This precipitate is filtered off, thoroughly washed with water containing sulphuretted hydrogen, and further tested for cadmium as given under 16.

8. Neutralize the filtrate from the previous experiment and mix it with ammonium sulphide. The precipitate formed, which may be termed D, is washed out with water containing ammonium sulphide and tested according to 10. *Magnesium* may also be contained in the filtrate.

9. To determine *magnesium*, evaporate a small quantity of the filtrate obtained in 8 and add some *sodium phosphate* and *ammonia*. If the solution contains magnesium a crystalline precipitate (of ammonium magnesium phosphate) is formed, which is insoluble in ammoniacal water.

10. Pour dilute *hydrochloric acid* over the precipitate D (from 8). If a black residue (consisting of sulphides of *nickel* and *cobalt*), and which may be termed E, is formed it is filtered off and further tested according to 11. Boil the filtrate until the sulphuretted hydrogen is completely driven off, then compound it with nitric acid, boil again and evaporate. Now compound it with strong alkaline lye in excess, boil and filter. The precipitate, which may

be termed F, is analyzed according to 12. The filtrate may contain zinc or alumina. Both are determined according to 13.

11. The residue E (from 10) is dissolved in hydrochloric acid, a few drops of nitric acid are added and the solution is evaporated nearly to dryness. By adding some *sodium nitrate* and *acetic acid*, and after standing for some time in the heat, a yellow precipitate is formed if *cobalt* be present. After 12 hours filter off and compound the filtrate with caustic soda. *Nickel* is present when a greenish precipitate is formed, which does not completely dissolve in the excess of the precipitating agent.

12. A portion of the precipitate F (from 10) is dissolved in hydrochloric acid and a sample of it tested,

a. With potassium ferrocyanide for *iron*.

b. Melt another sample with *potassium carbonate* and *potassium chlorate*, and boil the melted mass with water. If *chromium* was present it has been converted into chromic acid (yellow solution), and can be readily recognized by compounding the solution with *sugar of lead*. If chromium is not found, a portion of the sample is tested with the blow-pipe for *manganese*.

c. If chromium was found, a portion of the hydrochloric acid solution is neutralized with *potassium carbonate*, compounded with caustic soda in excess, and the precipitate tested for *manganese* and the filtrate for *zinc*, according to 13.

13. Moisten the solution to be tested for *manganese* upon a platinum-sheet with some soda and a trace of saltpetre, and let the flame of the blow-pipe act upon it. If the solution contains manganese a green paste is obtained, which on cooling turns blue-green. The filtrate from 10 may contain zinc or alumina. Compound a portion of it with sulphuretted hydrogen; a white precipitate (sulphate of zinc) indicates *zinc*. Acidulate another portion with hydrochloric acid, add ammonia in slight excess and warm. *Alumina*, if contained in the solution, is precipitated as aluminium hydrate.

14. The white precipitate *B* (from 4) may contain chloride of silver, chloride of lead or subchloride of mercury. Treat it with much *water* whereby chloride of lead is dissolved; the *lead* may

then be determined, as in 3, with sulphuric acid. Treat the residue with *ammonia*. If complete solution takes place the residue consists of chloride of silver, and from the solution the *silver* is again precipitated as chloride of silver by nitric acid. A black residue, insoluble in water and ammonia, consists of chlorine and *mercury* (subchloride of mercury).

15. The residue which remained by dissolving in nitric acid is warmed in aqua regia. If a white, insoluble powder is separated, it generally consists of chloride of silver, more rarely of chloride of lead. Though silver and lead by themselves are soluble in nitric acid, by alloying with the more noble metals they are frequently protected from solution, and may be contained in the residue. They are determined according to 14. A portion of the solution is now mixed with ferrous sulphate solution. A fine brownish separation consists of metallic *gold*. A yellow precipitate produced by sal-ammoniac confirms the presence of *platinum*.

If the residue A consists of a white powder it is washed off with water and boiled in a flask with tartaric acid. If it is soluble it consists of *oxide of antimony;* if insoluble it contains *tin*.

16. The precipitate *C* (from 7) obtained with sulphuretted hydrogen contains a number of metallic sulphides, a portion of which (antimony, arsenic, tin, gold, platinum) is dissolved by *ammonium sulphide*. The residue is boiled with dilute nitric acid and dissolves, separating flaky sulphur which floats upon the solution. If a portion remains undissolved it consists of *oxide of mercury*. From the filtered solution separate the lead by means of sulphuric acid (see 3) and after settling filter and mix with ammonia. A precipitate indicates *bismuth;* a blue coloration *copper*. Evaporate the solution completely, add some acetic acid and water and precipitate the copper with sulphuretted hydrogen. *Cadmium*, if present, is precipitated as sulphide of cadmium, and hence the precipitate has to be treated with boiling sulphuric acid. The sulphide of cadmium is dissolved while sulphide of copper remains undissolved. If the alloy contains cadmium *yellow sulphide of cadmium* is precipitated from the filtrate by sulphuretted hydrogen.

17. Some alloys contain *arsenic*, it being also found as an im-

purity in many metals. To complete the analysis a test for arsenic must, therefore, also be made. Marsh's apparatus is used for this purpose. It consists of a flask *a* (Fig. 3), in which hydrogen gas is developed from chemically pure zinc and dilute pure sulphuric acid. The tube *c* ends in a wide glass tube *d*, which is filled with calcium chloride for drying the gas. The gas escapes through the

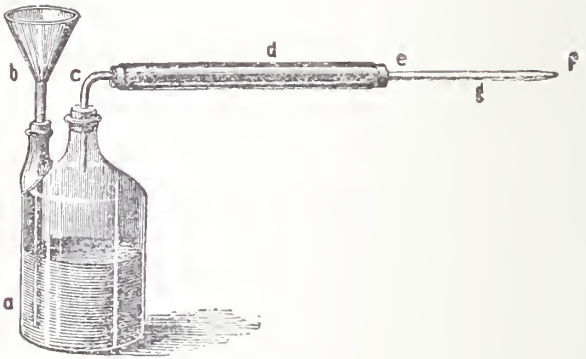


Fig. 3.

smaller tube *e*, running to a point at *f*. If now through the funnel *b* a few drops of the metallic solution are brought into the apparatus the flame of hydrogen will acquire a *blue* coloration if the solution contains arsenic, and a white smoke of arsenious acid will rise from it. The arsenietted hydrogen formed is very poisonous, a few bubbles of it being sufficient to cause death. If a piece of glass or porcelain is depressed upon the flame it will acquire a metallic mirror of arsenic. This metallic mirror, however, is not an infallible test, since *antimony* produces the same phenomenon. To ascertain whether arsenic or antimony has to be sought for in the metal drop a little solution of calcium chloride upon the metallic mirror; arsenic is immediately dissolved, while antimony remains unchanged.

To Distinguish Genuine from Spurious Gold.—Genuine gold dissolves in chlorine water and the solution has only a slightly yellowish color. Hence chlorine is a safe agent to distinguish genuine

from spurious gold. To test the genuineness of gilt articles rub a tiny drop of mercury on some corner of the surface to be examined; it will produce a white, silvery spot if the gold is pure or if there is gold in the alloy. If this silvery spot does not appear there is no gold in the surface exposed. To prove the correctness of this result a drop of a solution of nitrate of mercury can be dropped on the surface, when a white spot will appear if the gold is counterfeit, while the surface will remain unaltered if the gold is genuine. After the operation heating the article slightly will volatilize the mercury and the spots will disappear. Pure gold can be distinguished from its alloys by a drop of chloride of gold or of nitrate of silver. If the gold is pure there will be no stain, but if mixed with other metals the chloride of gold will leave a brownish stain upon it and the nitrate of silver a gray stain.

The simplest means of distinguishing genuine gold from a gold-like alloy consists in rubbing the article to be tested against an ordinary flint until a lustrous metallic coloring remains upon the latter. Now hold a strongly-sulphured burning match against the coloring; if it disappears from the flint the article is not gold.

To Test Gold Ware.—When a sample of the alloy cannot be had for a chemical test the touchstone forms a means of convenient examination. It consists of a species of black basalt obtained chiefly from Silesia. If a piece of gold be drawn across its surface a golden streak is left, which is not affected by moistening with nitric acid, whilst the streak left by brass or any similar base alloy would be rapidly dissolved. Experience enables an operator to determine by means of the touchstone nearly the amount of gold present in the alloy, comparison being made with the streaks left by alloys of known composition.

To Recognize Light Gilding upon Metallic Articles.—It is frequently of importance to know whether a metallic article has a thin coating of gold, or whether its gold-like appearance is due to a lacquer. To execute the test clean a piece or portion of the article to be tested with alcohol or ether and dissolve it in nitric acid free from chlorine. In case the article is gilded the layer of gold floats

upon or in the solution. In many cases treatment with chloroform is required, the removal of coatings of varnish not always being accomplished with alcohol or ether, and thus the layer of varnish which is not attacked by the acid would lead to error. The certainty of the presence of gold is best determined as follows: After complete solution of the article in nitric acid dilute the solution with water, filter through a small filter, wash out, dry and glow. The glowed residue is treated with the assistance of heat with a little aqua regia, poured off or filtered, if necessary, and the filtrate evaporated to dryness at a moderate heat. In the presence of gold a slight, lustrous separation of gold will frequently be observed on the sides of the evaporating vessel. Take up the residue of evaporation with about 0.12 to 0.18 cubic inches of water and divide the solution into three portions which are used for the following tests: Addition of a drop of concentrated solution of protochloride of tin: a content of gold gives a dark, brown separation. Addition of a drop of solution of ferrous sulphate gives a brownish or bluish separation, and addition of oxygenated water a blue separation.

To Recognize Light Silvering.—On touching silvered articles with a mixture of equal parts of bichromate of potassium and pure nitric acid of 1.35 specific gravity, a red stain is produced. To recognize light silvering apply to the article, previously cleansed with alcohol or ether, a drop of 1.5 per cent. solution of bisulphide of soda. After allowing the drop to act for 10 minutes rinse it off with water. Upon silvered articles a full, round, steel-gray spot is produced. Other white metals and alloys, with the exception of amalgamated copper, do not show this phenomenon, there appearing at the utmost a ring at the edge of the drop. Amalgamated copper is more quickly colored and acquires a more dead black color than silver. This test is so sensitive that the spot appears even if the silvering is so thin that the original color of the article shows through it.

Test-water for Silver.—This consists of 16 parts chromic acid and 32 of distilled water; keep the fluid in a well-stoppered glass bottle. File into the surface of the article to be tested, rub the filed place

upon the touchstone and apply the test-water. By detaching or rinsing off the latter with water it will be shown whether the article is silver or silvered. With silver the touch becomes blood-red, the coloration being the more intense the finer the silver. The touch of silvered German silver, tin, compositions, etc., is not decomposed by the test-water, the touch appearing in its original color, or, at the utmost, with a dull gray tint.

To Distinguish Tin-foil from Lead-foil.—Treat the foil with concentrated sulphuric acid; tin is dissolved, while lead remains undissolved.

To Test Mercury as to its Purity.—Pour nitric acid over a drop of mercury in a dish. If pure the mercury moves for a moment and then remains quiet and motionless. If it contains foreign metals it commences at once a vigorous circular motion which is kept up until the mercury is completely dissolved.

Tin is generally tested as to its purity by breaking it, whereby it gives out a single, crackling sound (the cry of tin). To recognize the nature of impurities dissolve a sample in aqua regia; *arsenic* and *antimony* are detected by Marsh's apparatus (see p. 70). Mix another portion of the solution with potassium ferrocyanide: a white precipitates indicates the purity of the tin; a blue precipitate generally the presence of *iron*, and a red-brown precipitate that of *copper*. Lead may be detected by the addition of sulphuric acid or Glauber's salt.

Soft Solders are tested in the same manner. They should contain only tin and lead. Some soft solders contain bismuth which is detected by diluting the solution (see under 2, p. 66).

To Detect Lead in Tin.—Make a solution of potassium bichromate in water. Next apply some acetic acid to the tin to be tested which will produce a whitish coating. Then apply some of the potassium bichromate solution and, if the whitish coating turns yellow, the tin contains lead, and the more the yellower the coating becomes.

To Test Brass.—With a larger content of lead brass becomes brittle. To detect the presence of lead add to the solution of the brass in nitric acid a few drops of sulphuric acid. A conclusion

of the quantity of lead present can be drawn from the volume of the precipitate.

White metals should always be tested with Marsh's apparatus. If the metallic mirror is only partially dissolved by chloride of lime, the sample contains *arsenic* and *antimony*. The other constituents are found in the manner already stated.

Copper has to be tested for arsenic, bismuth, lead, tin, zinc, iron, antimony and sulphur. By compounding the solution in nitric acid with barium nitrate a white precipitate insoluble in nitric acid is formed in case sulphur is present.

Nickel has only to be tested for copper, iron and cobalt. The manner of determining copper has been given under 5, p. 67. *Iron* can be recognized by its reaction with potassium ferrocyanide. To determine the presence of *cobalt* dissolve the metal in hydrochloric acid, dilute the solution with water and write with a goose quill upon a strip of white paper. After drying heat the writing; if it appears emerald-green to blue-green the solution contains cobalt. For other methods see under 11, p. 68.

Acids are readily tested for metallic acids according to the directions previously given. If uncertain as to the kind of acid to be tested it should be borne in mind that,

a, *hydrochloric acid* gives, with nitrate of silver, a precipitate of chloride of silver;

b, *sulphuric acid* gives, with a solution of barium chloride, a precipitate of barium sulphate.

c, *nitric acid* does not react upon both of the above solutions, but acquires a dark brown color by ferrous sulphate; however, if it contains hydrochloric acid it becomes turbid by nitrate of silver and is then unfit for dissolving silver, etc., and the preparation of pickle.

To Detect Alloys in Gilding.—A solution of chloride of copper will show the difference between gilding for which gold has been used and gilding with alloys of inferior metals. If the gilding be imitation gold, a touch of the solution will give a black mark, copper separating out through the zinc in the yellow metal; with pure metal no discoloration will occur. The test may also be effected with a solution of chloride of gold or nitrate of silver,

the first of which will give a brown spot, the second a gray or black spot; neither has any effect on gold. Common gold goods of 14-karat gold will not change their color with nitrate of silver. Leaf-gold is tested by being shaken up in a closed bottle with sulphuric chloride. Beaten gold will show no alteration, while "metal" leaves will grow gradually dark.

To Test Enamel for Lead.—For the simple and rapid detection of the presence of lead in the enamel of culinary vessels, apply a drop of concentrated nitric acid to the enamel of the carefully cleansed vessel and evaporate it to dryness by gentle heating. Then moisten the place which had been subjected to the action of the acid with a drop of sodium iodide, and the presence of lead will be indicated by the formation of yellow iodide of lead.

Ready Distinction of Cast-iron, Steel and Wrought-iron.—Apply a drop of nitric acid to the surface of the article to be tested, which should be previously made bright by filing. After allowing the acid to act for a few minutes wipe it off and rinse with water. Upon wrought-iron a dead white ash-gray spot will be clearly perceptible, upon steel a brownish-black one and upon cast-iron a deep black one. By this means it can be readily determined whether an article of wrought-iron is welded with steel and how far such welding extends. The entire test is based upon the difference of content of carbon in the above products of iron, cast-iron containing comparatively the greatest percentage of carbon, next wrought-iron and steel least; by the action of the nitric acid upon the metallic surface the iron is dissolved and the carbon exposed. A similar phenomenon appears in etching meteoric iron with nitric acid, peculiar figures being formed.

Method for Ascertaining the Quality of Iron and Steel.—Good iron is readily heated, is soft under the hammer and throws out few sparks.

Coarse grain with bright crystallized fracture or discolored spots indicates cold-short, brittle iron which works easily when heated and welds well. Cracks on the edge of a bar are indications of hot-short iron. A medium, even grain with fibres denotes good iron.

A soft, tough iron, if broken gradually, gives long silky fibres of leaden-gray hue, which twist together and cohere before breaking.

Badly refined iron gives a short blackish fibre on fracture. A very fine grain denotes hard, steely iron, likely to be cold-short and hard.

Examination of Burnt Iron.—The most recent method of testing iron is to microscopically examine the finely ground surface. The results of such examinations by Wedding were as follows: Burnt iron is characterized by the loosening of the coherence between the separate crystals constituting the solid iron. This loosening may take place at a temperature approaching the melting point in consequence of the formation of new crystals, or at lower temperatures, by reason of the crystals separating from each other (passing the limit of elasticity) in such a manner that by subsequent cooling off, the initial volume is not regained; it may, however, also take place by reason of a chemical change, which always consists in an absorption of oxygen.

The external appearance is, in all cases, nearly the same; the texture is coarse-grained, the separate grains showing a more or less lustrous surface, while the strength and ductility are diminished. For the regeneration of the iron it becomes necessary to destroy this coarse-grained texture, bringing at the same time the split crystals together either by hammering or rolling alone, or by the simultaneous reduction of the oxides. The oxide (as a rule magnetic oxide of iron, $Fe_3 O_4$) may also be reduced, without heating to the melting point. It is difficult to answer in a scientific way the question which method should be used for the regeneration of burnt iron; whether heating below the melting point or heating with fusion should be resorted to. In the Royal techno-chemical experimental station, at Berlin, sixteen tests were made, the results of which may be briefly stated as follows: 1. Burnt steel does not show the lustrous network of homogeneous iron which characterizes the unburnt product. 2. This network disappears to a greater extent the richer in oxygen the steel becomes. 3. White and, as a rule, lustrous planes appear more frequently and more perceptibly the more the steel

is burnt and the more coarse-grained its structure has become. 4. When burning has progressed to the formation of silicic acid, drop-like separations show themselves in place of crystallized iron, even with a fine-grained structure. 5. Highly-burnt steel which has become coarse-grained, shows plainly the dividing lines of the separate grains splitting still further. 6. Regenerated steel containing no silicic acid cannot be distinguished from sound steel. 7. Regenerated steel containing silicic acid shows a more intimate union of the grains, but can be plainly recognized by the dividing lines.

Resistance of a Few Metals and Alloys to Calcium Hydrate.—Filings and turnings of the metals to be examined, in quantities of 77 grains, were left, at a normal temperature, to the action of milk of lime with 4 per cent. hydrate for 14 days; they were then separated from the lime solution by washing until phenolpthaleine showed no longer a red coloration, dried and weighed. The results were as follows:

1. "Saxonia" pure soft lead: loss of weight 0.811 per cent. The metal was considerably attacked.

2. Antimony regulus: the metal remained entirely unchanged.

3. Lead pipe (with 25 per cent. slag lead): loss of weight, 0.299 per cent.; considerably attacked.

4. Lead plate (12 per cent. slag lead): loss of weight, 0.658 per cent.; considerably attacked.

5. Pure cast-iron: increase in weight, 0.014 per cent.; very much corroded.

6. Brass: loss of weight, 0.686 per cent.; considerably attacked.

7. Phosphor-bronze: no alteration.

8. Pure tin: loss of weight, 0.122 per cent.; the metal was but little attacked.

From these results it may safely be concluded that for pumps intended for the conveyance of milk of lime phosphor-bronze or an alloy of tin and antimony is most suitable.

How to Tell a Hand- from a Machine-cut File.—Take the file with the tang pointing towards you and turn it down under the

eye in such a way that the light will bring out prominently the rows of teeth. If you find the rows straight and regular you can at once make up your mind that it is a machine-cut file. If, on the other hand, you detect irregularities in "rowing," even if uniformity is broken in no other way, you can safely decide that the file is hand-cut. A double-cut file tried in this way very readily proclaims its make.

In some cases, however, hand-made files are cut with wonderful cleverness and nicety; so to be always safe—especially if your eye is inexperienced in such matters or is not naturally quick or keen, the better plan is to insist upon palpable regularity or irregularity in rowing, according to the make of file wanted. And right here it is recommended that when you have the leisure and the privilege, whether you want to buy files or not, that you compare the hand and the machine-cut article a few times under your eye; afterwards you will be quite as able to make distinctions as a file manufacturer himself.

Generally speaking, the hand-cut file is preferred for soft metals. Manufacturers of brass goods and kindred specialties frequently complain that the machine-cut file ridges the surface of the object filed, owing to the perfect regularity of the rows of teeth. Some manufacturers have attempted to overcome this prejudice by alternating the number of rows of teeth to the inch. Thus they will run sixteen rows with the machine to the inch, the next time fourteen, the third sixteen, and so on.

The best cutting file is the one with a true diamond tooth. If a file of this kind is held in the proper way, so that the point of the diamond is brought straight against the metal, the very heaviest cutting possible can be done. But it should be remembered in this connection that a good deal depends on the way the teeth are "rowed" on the file; the rows may lie in directions making it awkward, if not a matter of impossibility, for the user to present the teeth properly to the metal.

IV.

ALLOYS AND AMALGAMS.

I. *Alloys.*—Alloys are compounds of two or more metals. However, when one of the metals entering into combination is mercury, the result is usually not termed an alloy, but an *amalgam.* Many alloys possess the characteristics of a mixture and the mean properties of the metals of which they are composed, while others approach more closely chemical combinations and, consequently, partially show other properties than their components. As a rule, alloys are more readily destroyed by external influences than the pure metals, though there are exceptions which show the reverse. The color of an alloy frequently varies very much from that of the metals used in its preparation, though, as a rule, it approaches nearest to that of the metal present in greatest quantity. There are, however, some variations in this respect; an alloy consisting, for instance, of determined proportions of gold, silver and copper shows a greenish color, which, as is well known, does not appertain to any of these metals. The ductility and hardness of the metals also undergo considerable change in alloying. As a rule the ductility decreases, while the hardness compared with that of the metals constituting the alloy increases to a considerable extent. A few metals, for instance antimony, possess in a high degree the property of making metals harder.

The alloys, as a rule, fuse at a lower temperature than that at which the constituent most difficult to fuse becomes fluid. Thus platinum, which is scarcely fusible at all, readily combines with any of the inferior metals, zinc, tin and some others. Again, several of the readily fusible alloys melt below the boiling point of water, which is less than half the melting heat of tin, their most fusible ingredient.

The specific gravity of an alloy seems to depend upon the amount of cohesion or attraction exerted by the constituent metals for one another, and to bear no reference whatever to the high or low specific gravity of those constituents in their free state. It is

common among authorities, who publish determinations of specific gravities of the alloys, to give the calculated, as well as the observed, specific gravity. The calculated specific gravity is that which the alloy would have if there were neither expansion nor condensation of the metals during the act of combination. The specific gravities should be calculated from the volumes and not from the weights. Dr. Ure gives the rule as follows: Multiply the sum of the weights into the products of the two specific gravity numbers for a numerator, and multiply each specific gravity number into the weight of the other body, and add the products for a denominator. The quotient obtained by dividing the said numerator by the denominator is the truly computed mean specific gravity of the alloy."

The following table of the alloys, whose density is greater or less than the mean of their constituents, is given by several writers:

Alloys the Density of which is Greater than the Mean of their Constituents.	*Alloys the Density of which is Less than the Mean of their Constituents.*
Gold and zinc.	Gold and silver.
Gold and tin.	Gold and iron.
Gold and bismuth.	Gold and lead.
Gold and antimony.	Gold and copper.
Gold and cobalt.	Gold and iridium.
Silver and zinc.	Gold and nickel.
Silver and tin.	Silver and copper.
Silver and bismuth.	Iron and bismuth.
Silver and antimony.	Iron and antimony.
Copper and zinc.	Iron and lead.
Copper and tin.	Tin and lead.
Copper and palladium.	Tin and palladium.
Copper and bismuth.	Tin and antimony.
Lead and antimony.	Nickel and arsenic.
Platinum and molybdenum.	Zinc and antimony
Palladium and bismuth.	

The tenacity of an alloy is, as a rule, less than that of the most tenacious of the component metals, a very small quantity of lead, for instance, sufficing to decrease the tenacity of gold, which is one of the most tenacious of metals. In a few cases, however, the alloy possesses a higher degree of tenacity than the constituent metals, there being, for instance, an alloy of copper and zinc

which is more ductile than copper, though zinc belongs to those metals which are distinguished by brittleness rather than by ductility.

Alloys are generally made by directly melting together the metals which are to take part in the mixture. The operation may be carried on in an earthenware crucible when small quantities are being operated upon; but for manufacturing on a large scale a reverberatory furnace, preferably heated with gas, should be employed to effect the melting. The melting and mixing of the several metals is a point which is far from being reduced to anything like a system in many establishments, and practical men are often at a loss as to the proper means for securing a definite and uniform alloy. As a general rule it is necessary to melt the less fusible metal first and to add the more fusible afterwards. Founders generally are of the opinion that if the metal of the first melting is run out into a bar and then remelted a more complete incorporation is obtained. Where a great difference exists in the specific gravities of the component metals, it is necessary to observe certain fixed rules in order to obtain a perfectly homogeneous mixture; each metal tends to find its own particular level in the liquid compound, according to its density; therefore, if the casting is of considerable size and requires a long time to cool, a partial separation will often take place, the lightest rising to the surface. Therefore, the metals, while in a state of fusion, must not be allowed to remain quiescent, but an intimate mixture be effected by vigorous stirring, sticks of dry soft wood being in many cases used for this purpose. By stirring the fused mass with one of these sticks, the wood is more or less carbonized according to the temperature of the mass. In consequence of the dry distillation of the wood taking place thereby, there is evolved an abundance of gases which, by ascending in the fused mass, contribute to its intimate mixture. The stirring should be continued for some time and the alloy then cooled as rapidly as possible. When three metals have to be united together, they should first be melted in pairs and afterwards together.

The following may serve as general rules for fusing the metals:

1. The melting-pot should be red hot, and those metals first placed in it which require the most heat to fuse them. 2. Put the metals in the melting-pot in strict order, following exactly the different fusing points from the highest degree of temperature required down to the lowest, in regular sequence, and being especially careful to refrain from adding the next metal until those already in the pot are completely melted. 3. When the metals fused together in the crucible require very different temperatures to melt them, a layer of charcoal should be placed upon them, or if there is much tin in the alloy, a layer of sand should be used. 4. The fused mass should be vigorously stirred with a stick, and even while pouring it into another vessel the stirring should not be relaxed. 5. In making new alloy, use a little old alloy of the same kind, if there be any on hand. 6. Make sure that the melting-pots are absolutely clean and free from traces of former operations.

The fusing points of the principal metals and other elements employed in alloys are as follows:

Aluminium	1292° F.	Lead	626° F.
Antimony	797 "	Mercury	—40 "
Arsenic	773 "	Nickel	2732 to 2912 "
Bismuth	504 "	Phosphorus	111 "
Cadmium	608 "	Platinum	4712 "
Copper	1922 "	Silver	1832 "
Gold	2282 "	Sulphur	239 "
Iron, cast	1922 to 2192 "	Tellurium	716 "
" wrought	2732 to 2912 "	Tin	455 "
Steel	2372 to 2552 "	Zinc	773 "

Alloys of Bismuth and Cadmium.—These alloys have the peculiarity that their melting points are far below those of their constituent metals, some of them even melting in hot water. They can be used for casting in moulds which will not stand great heat, for instance moulds of paper, wood, plaster of paris, etc. The composition of the most important alloys belonging to this group is given in the following table:

	Melts at ° F.	Lead. Parts.	Tin. Parts.	Antimony. Parts.	Cadmium. Parts.	Bismuth. Parts.
Lipowitz's alloy	158	8	4	..	3	15
Readily fusible alloy	170	11	3	..	2	16
" " "	167	8	3	..	10	8
" " "	203	..	2	..	1	3
" " "	150	2	1	..	1	4
Wood's alloys	140 to 161.6	4	2	..	1 to 2	5 to 8
Soft solder	179.6	6	..	..	1	7
" "	300.2	2	4	..	2	
Cliché metal	....	50	36	..	22.5	
" "	....	32.5	48	..	10.5	9
Metallic cement	....	8	..	3	..	1
Newton's metal	202	5	3	..	..	8
Rose's metal	200.75	1	1	..	..	2
" "	174.2	8	3	..	..	8
Readily fluid metal suitable for impressions of plaster of paris moulds, wood engravings, medals, etc.		13	3	..	..	6
		3	2	..	..	5
		1	1	..	..	2
		5	3	..	..	8
Glass cement	212	3	2	..	..	2.5
Bismuth alloys	212	5	3	..	..	8
" "	235 9	8	4	..	..	8
" "	253.9	8	8	..	..	8
" "	266	10	8	..	..	8
" "	270.3	12	8	..	..	8
" "	287.9	16	14	..	..	8
" "	293.7	16	12	..	..	8
" "	308.8	22	24	..	..	8
" "	320.3	32	36	..	..	8
" "	330.7	32	28	..	..	8
" "	341.6	30	24	..	..	8

Alloys of Copper and Tin.—Bronze. The alloys produced by the union of copper and tin are termed "*bronze*" in the actual sense of the word if the copper is present in predominating quantity, while those in which the content of tin predominates are called "*white metal.*" Bronze has been known and employed from very remote ages. It was used exclusively by the ancients for making swords and other sharp instruments, for coinage, statues and many other useful and ornamental purposes. Great variations are made in the proportions of the two chief ingredients, according to the nature of the application for which the alloy is intended. The addition of a little zinc to the alloy is an advantage, but too much of it

diminishes its tenacity; lead is objectionable, owing to its tendency to sink after casting, thus destroying the homogeneity of the alloy. The metals should be melted rapidly to prevent loss of metal by oxidation, and the melted mass should be covered with a layer of charcoal and kept constantly stirred. The operation is generally carried on in refractory crucibles, heated in a reverberatory furnace of suitable form. The cooling in the moulds must be as rapid as possible, in order to prevent the liquation of the metals.

Ordnance or Gun-metal.—Gun-metal contains on an average 90 to 91 per cent. of copper and 9 to 10 per cent. of tin; sometimes it contains some lead and zinc. The principal requisite of an alloy answering all the demands of a good ordnance bronze is the production of entirely homogeneous castings, which it is endeavored to attain by solidifying the alloy under conditions allowing of its uniform cooling off. The moulds are always placed in a vertical position, and the evil of the upper portions of the casting showing frequently a different composition from the lower, is counteracted by using an excess of bronze, so that the finished casting has a long piece on top, the so-called "dead-head or "sullage-piece," which is later on sawed off and remelted with a new charge. This dead-head contains the greater portion of the liquated metal, and also the so-called "waste" consisting of oxidized metal.

The following table shows the composition of ordnance bronze of various times and different countries:

	Copper Parts.	Tin. Parts.	Lead. Parts.	Zinc. Parts.	Iron. Parts.	Brass. Parts.
United States	90	10	....	....	....	
France (modern)	90.09	9.9	....	....	....	
Prussia	90.90	9.1	....	....	....	
England	89.30	10.7	....	....	....	
France (1780)	100	....	....	....	....	61.0
Savoy (Turin, 1771)	100	12.0	....	....	....	6.0
Russia (1819)	88 61	10.7	....	...	0.69	
Lucerne (Switzerland)	88.929	10.375	0.062	0.419	0.110	
Cochin-China	77.18	3.42	13.22	5.02	1.16	
	93.19	5.43	....	....	1.38	
China	71.16	....	....	27.36	1.40	
Turkey (1464)	89.58	10.15	....	....	....	
	95.20	4.71	....	....	....	

Steel Bronze or Uchatius Bronze.—The ordnance bronze known under this name is prepared in the Austrian arsenals, the method of melting and subsequent treatment in casting being kept secret. It is only known that the bronze contains 8 per cent. of tin and that the casting, is effected in cold moulds. In casting a copper rod about 2 inches in diameter is inserted as a core in the centre of the iron mould. It serves as a conductor of heat and later on is bored out. The alloy is crystalline and of a gold-yellow color. To increase the solidity of the piece steel bolts with a diameter of from 0.39 to 2.36 inches are forced in by means of a hydraulic press.

Bell-metal contains on an average 78 per cent. of copper and 22 per cent. of tin. The color of good bell-metal is a peculiarly gray white, differing materially from that of ordnance bronze and statuary bronze. Bell-metal is hard, brittle and sonorous and exhibits a fine-grained fracture. Cooled suddenly from a red heat it becomes soft, but regains its hardness after being reheated and cooled very slowly. The larger the proportion of copper in the alloy the deeper and graver is the tone of the bells formed from it. The addition of tin, iron or zinc causes them to give out a sharper tone. The opinion was formerly held that an addition of silver adds to the beauty of the tone, though at present it is thoroughly understood that such is not the case. The melting and casting of bell-metal is not so difficult as that of ordnance bronze, though great analogy exists between them. The copper is first melted down, and after heating the fused mass as much as possible the tin is introduced and an intimate mixture promoted by vigorous stirring. Many bell-founders do not add all the tin at once, but at first about two-thirds of it, and when this has formed a union with the copper the other third.

Chinese Tam-tams or Gongs are distinguished by a strong far-reaching sound. The alloy of which they are made is nearly of the same composition as the ordinary bell-metal, the difference in sound being due to mechanical treatment. As soon as the plates intended for the manufacture of tam-tams are well solidified, they are withdrawn from the mould and introduced into a furnace where they are raised to a cherry-red heat. They are then inserted

between iron disks, plunged into water and allowed to cool, after which they are withdrawn, and are so tenacious that they may be worked under the hammer.

The following table shows the composition of some bell-metals:

	Parts.						
	Copper.	Tin.	Zinc.	Lead.	Silver.	Iron.	Antimony.
Standard, very sonorous	39	11	....	....	....	....	
Founders' standard, paler and inferior to above	77	21	....	....	....	....	2
Very deep toned and sonorous	40	10	....	....	....	....	
For church and other large bells	30	10	....	....	....	....	
Alarm bell at Rouen	76.1	22.3	1.6	....	1.6	....	
" " " Ziegenhain	71.48	33.59	....	4.04	....	0.12	
" " " Darmstadt	73.94	21.67	....	1.19	0.17	....	
" " " Reichenhall (13th Century)	80	20	....	....	....	....	
Tam-tam	78.51	10.27		0.52	0.18	....	
	10	4	1.5	....	0.5	....	
Bells of Japanese origin	10	2.5	0.5	1.33	....	....	
	10	3	1	2	0.5	....	
	10	....	....	....	....	....	

Bell-metal for Small Bells, which is said not to tarnish nor crack and to be very light in weight and give an excellent sound, is composed of copper, 3 lbs.; nickel, ½ lb., melted and cooled; then add ½ lb. zinc and ¼ oz. aluminium; melt and cool. Melt again and add ¼ oz. mercury and 3 lbs. melted copper.

Japanese Bell-metal.—This alloy, called "Karakane" by the Japanese, is cast in various qualities. I. Copper, 10 parts; tin, 4; iron, ½; zinc, 1½. II. Copper, 10 parts; tin, 2½; lead, 1⅓; zinc, ½. III. Copper, 10 parts; tin, 3; lead, 2; iron, ½; zinc, 1. IV. Copper, 10 parts; tin, 2; lead, 2.

Small Clock-bells, Table-bells, Sleigh-bells, etc.—For these an alloy giving a clear and pure tone has to be used. The following table will suffice to show the composition of such alloys:

	Parts.						
	Copper.	Tin.	Zinc.	Lead.	Silver.	Antimony.	Bismuth.
House-bells	80	20					
" " smaller	75	25					
Clock-bells, German	73	24.3	2.7				
" " Swiss	74.5	25	....	0.5			
" " Paris	72.0	26.56	....	....	1.44		
Sleigh-bells	84.5	15.42	....	....	....	0.1	
White table-bells	17	800	....	....	....	....	5
" " "	....	7	....	....	....	1	

Silver Bell-metal.—This alloy, suitable for small bells, is distinguished by a beautiful silver-clear tone and a nearly white color. It is composed of

	Parts.		
	I.	II.	III.
Copper	40	41.5	41.6
Tin	60	58.5	58.4

Machine Bronze.—In this collective term are included a great number of alloys with very variable properties, and which have actually nothing in common except that they are used for certain parts of machines. Many of these mixtures of metals must be as hard as possible in order to resist wear; others must possess great strength, so as not to yield under shocks or pressure; while still others must have the property of showing even under a heavy load but little frictional resistance when in contact with other metals. There are two kinds of bearing-metal, viz.: *red brass* and *white metal,* the former being bronze-like alloys with from 82 to 89 per cent. of copper and 11 to 18 per cent. of tin. By the addition of zinc, lead and antimony, the hardness or ductility of the alloy is changed according to the purpose for which it is to be used. An addition of lead facilitates the working of the alloy but also favors liquation; antimony increases the hardness of the alloy.

White bearing metal is distinguished from red brass by being more readily fusible, so that it can frequently be cast around the respective pivot. It consists of tin, 74 to 91 per cent., antimony, 6 to 15, and copper, 2 to 11. The copper increases the hardness and strength of the alloy. In English bearing-metal a portion of the tin is replaced by zinc or lead. Small quantities of other metals besides tin, lead, zinc, antimony and copper, which occur in the alloys, must be considered as impurities of the metals used.

METALS FOR BEARINGS, ETC.

I. Red Brass Bearings, etc.	Parts.			
	Copper.	Zinc.	Tin.	Lead.
For locomotive axles	86	14		
" " "	82	8	10	
" railroad car axles	82	18		
" " " "	84	16		
" " " "	75	2	20	
" various axles	73.7	2.1	14.2	
" " " (medium hard)	69.55	5.88	21.77	
" " " (hard)	82	2	16	
" " " (very hard)	88.8	11.2		
" cog-wheels	91.3	8.7		
" punches	83.3	16.7		
" steam-whistles	80	2	17	
" " "	81	2	16	
" cocks	88	2	10	
" boxes for wagon-wheels	87.7	2.6	9.7	
" stuffing-boxes	86.2	3.6	10.2	
" mechanical instruments	81.2	5.1	12.8	
" files	64.4	10	17.6	8.6
" "	61.5	7.7	30.8	
" weights	90	2	8	
" castings to be gilded	79.1	7.8	13.1	
" " " "	77.2	7	15.8	
" shovels (malleable)	50	16.4	33.6	
" " "	3	2	1	
" buttons (white)	57.9	36.8	5.3	
" sheet for pressed articles	63.88	30.55	5.55	
" small castings	94.12	.....	5.88	
" " "	90	10		
" piston rings	84	8.3	2.9	4.3
" pump barrels	88	2	10	
" eccentric straps	90	2	8	

METALS FOR BEARINGS, ETC.—*Continued.*

II. White Metal Bearings.	Parts.					
	Tin.	Antimony.	Zinc.	Iron.	Lead.	Copper
German for light loads	85	10	.....	.....	.....	5
" " " "	82	11	.....	.....	.....	7
" " " "	80	12	.....	.....	.....	8
" " " "	76	17	.....	.....	.....	7
" " " "	3	1	5	.....	3	1
" " heavy "	90	8	.....	.....	.....	2
" " " "	86.81	7.62	.....	.....	.....	5.57
English for heavy loads	17.47	.....	76.14	.....	.....	5.62
" " medium "	76.7	15.5	.....	.....	.....	7.8
" " " "	72	26	.....	.....	.....	2
For mills	15	.....	40	.....	42	3
" "	.....	1	5	.....	5	
" "	.....	1	10	.....	2	
For heavy axles	72.7	18.2	.....	.....	.....	9.1
" " "	38	6	47	.....	4	1
For rapidly revolving axles	17	77	.....	.....	.....	6
Bearings of great hardness	5	.....	.....	70	.....	2.5
" " "	12	82	2	.....	.....	4
" (cheap)	2	2	88	.....	.....	8
" "	1.5	1.5	90	.....	.....	7
For railroads :—						
Prussia	91	6	.....	.....	.....	3
"	85	10	.....	.....	.....	5
"	80	12	.....	.....	.....	8
Prussian and Hanoverian railroads approved under the heaviest pressure	86.81	7.62	.....	.....	.....	5.57
Bavaria, durable cold running	90	8	.....	.....	.....	2
Austria government railroad	90	7	.....	.....	.....	3
Distributing slide valves	83.2	11.2	.....	.....	.....	5.6
Railroad cars and larger machines	.....	16	.....	.....	84	
Railroad cars, harder and stronger	20	20	.....	.....	60	
	.....	12	.....	8	80	

Locomotive Brass Castings.—The following compositions are highly recommended :

Brasses for Side Rods.—Copper, 6 lbs. ; tin, 1 lb. To 100 lbs. of this mixture add ½ lb. each of zinc and lead.

Brasses for Driving-Boxes.—The same as for side rod brasses.

Some master mechanics prefer harder brasses and call for 5 lbs. of copper and 1 lb. of tin, ½ lb. of zinc and ½ lb. of lead.

Bells.—Copper, 4 lbs.; tin 1 lb. To every 100 lbs. of this mixture add zinc, ½ lb., and lead ½ lb.

Castings subjected to Steam Pressure.—Copper, 20 lbs.; tin, 1½ lbs.; lead and zinc, of each 1 lb.

Pumps and Pump Chambers.—Copper, 8 lbs.; tin, 1 lb. To every 100 lbs. of this mixture add 1½ lbs. each of lead and zinc.

Piston Packing Rings.—Copper, 16 lbs.; tin, 2¼ lbs. To every 100 lbs. of this mixture add 1 lb. each of zinc and lead.

Approved Compositions for Bearings of Rapidly Running Machines.—I. Tin, 17 parts; antimony, 77; copper, 6. II. Copper, 86 parts; zinc, 14. III. Copper, 82; zinc, 18. IV. Copper, 84; zinc, 16. V. Copper, 100; zinc, 10; tin, 3. VI. Tin, 17.47; zinc, 76.14; copper, 5.69.

Bearing Metals for Locomotives.—I. Copper, 86 parts; tin, 14. II. *Dutch.* Copper, 85.25 parts; tin, 127.5; zinc, 2. III. *Approved Belgian.* Copper, 80 parts; tin, 16; lead, 2; antimony, 2. IV. *French Northern Railroad.* Copper, 82 parts; tin, 10; zinc, 8. V. Copper, 87.5 parts; tin, 7.88; zinc, 5.07. VI. Copper, 79.5 parts; tin, 7.5; zinc, 5; lead, 8.

Babbitt's Anti-Attrition Metal is made by melting separately 4 parts of copper, 12 of Banca tin, 8 of regulus of antimony and adding 12 parts of tin after fusion. The antimony is added to the first portion of tin and the copper is introduced after taking the melting-pot away from the fire and before pouring it into the mould. The charge is kept from oxidation by a surface coating of powdered charcoal. The "lining metal" consists of this "hardening" fused with twice its weight of tin, thus making 3.7 parts copper, 7.4 parts antimony and 88.9 tin. The bearing to be lined is cast with a shallow recess to receive the Babbitt metal. The portion to be tinned is washed with alcohol and powdered with sal-ammoniac, and those surfaces which are not to receive the lining metal are to be covered with a clay wash. It is then warmed sufficiently to volatilize a part of the sal-ammoniac and tinned.

The lining is next cast in between a former, which takes the place of the journal and the bearing.

Fenton's Alloy for Axle-Boxes for Locomotives and Wagons.—Zinc, 80 parts; copper, 5½; tin, 14½. This alloy may be recommended as regards cheapness and lightness.

Dewrance's Patent Bearing for Locomotives.—Copper, 4 parts; tin, 6; antimony, 8.

Alloy for Anti-Friction Brasses.—Zinc, 80 parts; tin, 14; copper, 5; nickel, 1.

Hoyle's Patent Alloy for Pivot Bearings.—Tin, 24 parts; lead, 22; antimony, 6. It is claimed to stand friction without heating longer than any other composition.

Phosphor Bronze, which is largely used as a substitute for bronze and gun-metal compositions, for gearing, bearings, wire rope, etc., is an alloy of copper and tin, which has been fluxed by the introduction of a variable quantity of phosphorus, which is generally added in the form of phosphide of copper or phosphide of tin. *Phosphide of copper* is prepared by heating a mixture of 4 parts of super-phosphate of lime, 2 parts of granulated copper and 1 part of finely pulverized coal in a crucible at not too high a temperature. The melted phosphide of copper, which contains 14 per cent. of phosphorus, separates on the bottom of the crucible. According to another method phosphide of copper is prepared by adding phosphorus to copper sulphide solution and boiling, adding sulphur as the sulphide is precipitated. The precipitate is carefully dried, melted and cast into ingots. When of good quality and in proper condition it is quite black.

Phosphide of Tin is prepared as follows: Place a bar of zinc in an aqueous solution of chloride of tin, collect the sponge-like tin separated, and bring it moist into a crucible, upon the bottom of which sticks of phosphorus have been placed. Press the tin tightly into the crucible and expose it to a gentle heat. Continue the heating until flames of burning phosphorus are no longer observed on the crucible. After the operation is finished a coarsely-crystalline mass of a tin-white color, consisting of pure phosphide of tin, is found upon the bottom of the crucible.

The addition of phosphorus to bronze prevents the formation of oxide, by which the strength, ductility and homogeneity of the resulting alloy would be impaired, and furnishes a metal which in respect to these qualities is notably superior to ordinary bronze. Numerous grades of phosphor bronze are made according to the uses for which it is intended. However, according to Thurston, five sorts are considered to answer all requirements:

0. *Ordinary phosphor bronze* of 2 per cent. phosphorus. 1. *Good phosphor bronze* of 2½ per cent. phosphorus. These two numbers are in all cases superior to ordinary bronze and steel. 2. *Superior phosphor bronze* of 3 per cent. phosphorus. 3. *Extra phosphor bronze* of 3½ per cent. of phosphorus. 4. *Maximum phosphor bronze* of 4 per cent. of phosphorus. These three, according to Delalot, are superior to any other bronzes. Above No. 4 phosphor bronze is useless; below No. 0 it is inferior to common bronze and steel. Nos. 3 and 4 are comparatively unoxidizable.

Silicon-bronze is a combination of copper with silicon; its tenacity is as great as that of phosphor-bronze, and its power of conducting electricity considerably larger. It is chiefly used for telephone-wires which with the same conducting power have only $\frac{1}{10}$ the weight of ordinary wires. The following shows the composition of some of these alloys:

Telephone-wire A.		*Telegraph-wire A.*	
Copper	99.94 per cent.	Copper	97.12 per cent.
Tin	0.03 " "	Tin	1.14 " "
Silicon	0.02 " "	Silicon	0.05 " "
Iron	trace " "	Iron	trace " "
Zinc	——	Zinc	1.62 " "
	99.99 per cent.		99.93 per cent.

Silicon-brass.—Copper, 71.30 per cent.; zinc, 26.65; lead, 0.74; tin, 0.57; iron, 0.38; silicon, 0.14.

Statuary Bronze.—The bronze at present used for statues contains, on an average, copper, 86.6 per cent.; tin, 6.6; lead, 3.3, and zinc, 3.3. A statuary bronze which thoroughly answers the purpose must become thinly fluid in fusing, fill the moulds out sharply, allow of being readily worked with the file, and must

acquire a beautiful green color, the patina, on exposure to the air for a short time. Statuary bronze being chiefly used for artistic purposes, its color is of great importance.

The following table gives a series of alloys of different colors suitable for the purpose:

Copper.	Zinc.	Tin.	Color.
84.42	11.28	4 30	red-yellow.
84.00	11.00	5.00	orange-red.
83.05	13.03	3.92	" "
83.00	12.00	5.00	" "
81.05	15.32	3.63	orange-yellow.
81.00	15.00	4.00	" "
78.09	18.47	3.44	" "
73.58	23.27	3.15	" "
73.00	23.00	4.00	pale-orange.
70.36	26.88	2.76	pale-yellow.
70.00	27.00	3.00	" "
65.95	31.56	2.49	" "

In the following table will be found the compositions of a few celebrated statues:

	Parts.						
	Copper.	Zinc.	Tin.	Lead.	Iron.	Nickel.	Antimony.
Column Vendome (Paris)..	89.20	0.5	10.2	0.1			
Column of July (Paris)....	91.40	5.6	1.6	1.4			
Henry IV. (Paris).....	89.62	4.2	5.7	0.48			
Keller's Louis XIV.....	91.4	5.53	1.7	1.37			
Napoleon I..... ..	75.0	2.00	3 0	2.00			
The Shepherd, Potsdam Palace.....	88.68	1.28	9.2	0.77			
Bacchus, Potsdam Palace..	89.34	1.63	7.5	1.21	0.18		
Germanicus, Potsdam.....	89.78	2.35	6 16	1.33	....	0.27	
Augsburg bronze.....	89.43	....	8.17	1.05	0.34	0.19	
" "	94.74	0.54	1.64	0.24	....	0.71	0.84
Münich bronze.....	77.03	19.12	0.91	2.29	0.12	0.43	
" "	92.88	0.44	4.18	2.31	0.15		

Best Bronze for Statues According to D'Arcet.—Copper, 78.5 parts; zinc, 17.2; tin, 2.9; and lead, 1.4; or, copper, 164 parts; zinc, 36; tin, 6; and lead, 3.

Bronze for Gilding.—This should be fusible at a low temperature, compact and close-grained. Copper, 82.25; zinc, 17.50; and tin, 0.25; takes gilding well.

Bronze for Small Castings.—An excellent bronze for this purpose is composed of copper, 94.12 parts; tin, 5.88. It becomes very thinly fluid in the heat and fills out the moulds well.

Bronze which can be Rolled.—A bronze containing 4.5 to 7 parts of tin to 100 of copper can be readily rolled out to sheets at a red heat.

Chinese Bronzes.—Analyses of different specimens of Chinese bronze gave the following results:

Name.	Parts.		
	I.	II.	III.
Tin	4.36	5.52	7.27
Copper	82.72	72.09	72.32
Lead	9.9	20.31	14.59
Iron	0.55	1.73	0.28
Zinc	1.86	0.67	6.00
Arsenic	——	trace	trace

Delta-metal is an alloy of zinc, iron and copper, which receives during fusing an addition of phosphorus and, according to the desired properties, a further addition of tin, manganese and lead. It has the color of a gold-silver alloy, and can be worked cold as well as hot; it cannot be welded; with some care it may, however, be soldered. It does not rust. On account of its great tenacity it is used in place of steel for torpedoes, bicycles, ship-chains, in the construction of steamboats, etc.

Delta-metal as manufactured by the "Deutsche Delta-Metall Gesellschaft" is composed as follows:

Name	Cast.	Wrought.	Rolled.	Hot punched.
	Per cent.	Per cent.	Per cent.	Per cent.
Copper	55.94	55.80	55.82	54.22
Lead	0.72	1.82	0.76	1.10
Iron	0 87	1.28	0.86	0.99
Manganese	0.81	0.96	1.38	1.09
Zinc	41.61	40.07	41.41	42.25
Nickel	trace	trace	0.06	0.16
Phosphorus	0.013	0.011	trace	0.02
	99.963	99.941	100.29	99.83

Gold Bronze.—Copper, 90.5 parts; tin, 6.5; zinc, 3. This alloy retains its beautiful gold color on exposure to the air, but loses it rapidly if exposed to both air and water.

Japanese Bronze.—M. E. J. Maumené gives the results of an analysis of Japanese bronzes as follows:

Name.	Parts.			
	I.	II.	III.	IV.
Copper	86.38	80.91	88.70	92.07
Tin	1.94	7.55	2.58	1.04
Antimony	1.61	0.44	0.10	1.04
Lead	5.68	5.33	3.54	1.04
Zinc	3.36	3.08	3.71	2.65
Iron	0.67	1.43	1.07	3.64
Manganese	0.67	trace	1.07	3.64
Silicic acid	0.10	0.16	0.09	0.04
Sulphur	0.10	0.31	0.09	0.04
Waste	0.26	0.79	0.21	0.56

Malleable Bronze.—A patent has been taken out both in England and France by Messrs. A. Sentex, C. Marshall and A. Saunier, establishing a process for producing malleable and ductile bronze bars or plates which are free from cracks and blow-holes, are "unoxidizable" and which may be "rolled and drawn with the greatest ease," and, moreover, have the appearance and "sonorousness of

gold:" 3.3 lbs. of tin are purified by melting under nitre; 22 lbs. of copper are melted and 1.76 ozs. of equal parts of nitrate and cyanide of potassium are added for the double purpose of reducing the oxides and "fattening" the metal. Then 0.88 oz. of bitartrate of potassium with the same quantity of cyanide is added, and, after poling, the tin is introduced; 0.88 oz. each of sal-ammoniac and cyanide are thrown on; 15.43 grains of "phosphuret of copper" introduced to "impart mildness," and 0.7 oz. of "Marseilles soap" added, which still further fattens the metal. Finally 15.43 grains of sodium are added at the moment of casting. The metal, if cast in sand, may contain zinc, and, the portion of tin reduced, the quantity of phosphorus and sodium may be increased.

Old Peruvian Bronze.—An old chisel, weighing about 7 ozs., found in Quito, showed, according to Boussingault, the following composition: Copper, 95 parts; tin, 4.5; lead, 0.2; iron, 0.3; silver, traces.

Ormolu.—This bronze is distinguished by a pure golden-yellow color and requires but very little gold for gilding. It is much used for the finest bronze articles of luxury. It is composed of copper, 58.3 parts; tin, 16.7; zinc, 25.3.

Silveroid.—This alloy, which has been recently brought into commerce by H. Wiggin, consists of copper and nickel, to which, according to the purpose for which it is intended, zinc, tin and lead are added. The alloy is very white, lustrous, fine-grained and of great tenacity. It is used as a substitute for gun-metal and brass where a lustrous color and polish are required.

Speculum-metal.—The alloys known under this name are employed for making metallic reflectors, requiring a true white color, good lustre and a hard, clean surface not easily tarnished or scratched. Speculum-metal contains on an average from 64 to 69 per cent. of copper and 30 to 35 per cent. of tin. To heighten the white color small quantities of arsenic and antimony are sometimes added.

The following table shows the composition of some alloys used for speculum-metal:

Name.	Parts.				
	Copper.	Tin.	Zinc.	Arsenic.	Other metals.
Standard alloy	68.21	31.79			
Otto's	68.5	31.5			
Richardson's	65.3	30	0.7	2	2 Silver.
Mudge's	65	35			
Little's	65	30.8	2.3	1.9	
Sallit's	64.6	31.3	....	....	4.1 nickel.
Chinese	80.83	....	....	....	8.5 antimony.
Old Roman	63.9	19.05	....	....	17.29 lead.

Alloys of Copper and Zinc. Brass and Similar Alloys.—Brass is an alloy of copper and zinc in varying quantities. Ordinary brass contains from 18 to 50 per cent. of zinc (on an average to 2 parts of copper 1 part of zinc). With a larger content of copper the color becomes reddish and the alloy is called *tombac*. Tombac contains at the utmost 18 per cent. of zinc; it is especially used where great ductility, flexibility and but little hardness are required, as, for instance, for fine works of wire and sheet, or where a reddish shade of color is desired, for instance, for articles which are to be gilded. For most technical purposes, however, brass richer in zinc is employed, mostly because, on account of the greater content of zinc, it is cheaper and besides more readily fusible. Brass for ordinary coarser castings consists generally of alloys with a high content of zinc, which, besides, are frequently produced from the more impure raw materials. But brass for the fabrication of sheet and wire is made from the purest materials and contains less zinc than cast-brass, generally from 25 to 35 per cent., exceptionally only up to 37 per cent. Besides copper and zinc, brass frequently contains very small quantities of other metals (tin, lead, iron), which are seldom intentionally added, but mostly come from impurities of the component metals. The color of copper-zinc alloys varies according to the content of tin and will be seen from the following table:

Color of Copper-Zinc Alloys.

Content of zinc.	Color.	Content of zinc.	Color.
5 per cent	red.	35 per cent	dark yellow.
10 "	red-brownish.	38 "	dark yellow.
16 "	red-yellow.	41 "	reddish-yellow.
20 "	reddish-yellow.	50 "	beautiful gold-yellow
22 "	reddish-yellow.	60 "	bismuth-gray.
25 "	pale yellow.	70 "	antimony-gray.
27 "	yellow.	80 "	zinc-gray.
30 "	yellow.	90 "	zinc-gray.

To brass belong also a number of copper-zinc alloys for definite purposes; for instance, Aich's metal, oroide, etc., the composition of which is given in the following table:

COMPOSITION OF COPPER-ZINC ALLOYS.

I. *Tombac (Red Brass) and Similar Alloys.*

Name.	Copper.	Zinc.	Tin.	Lead.	Various metals.
Tombac, from Ocker	85	15			
" " Iserlohn	92	8			
" " Hegermühle	85.3	14.7			
English tombac for castings	86.4	13.6			
Tombac for fine sharp castings	87	13			
" " gun mountings	80	17	3		
Nürnberg tombac for Dutch gold	84.6	15.4			
Tombac for jewelry (chrysochalk)	90	7.9			
Tombac resembling gold	89.97	9.96	0.05		
" " "	82	17.5	0.5		
Tombac for gilding	86	14			
" (d'Arcet)	82.5	17.5			
Sheet for buttons	99.15	0.85			
" " "	84.21	15.79			
Austrian axle journals	92.5	7.5			
Pinchbeck for fancy articles	93.6	6.4			
Oroide	90	10			
"	85.5	14.5			
Talmi gold	86.4	12.2	1.1	....	0.3 iron.
Similor or Mannheim gold	89.44	9.93	0.62		
Tournay's metal (for buttons)	82.54	17.46			
Tissier's metal (very hard)	97	2	.....	.....	1 to 2 arsenic.

COMPOSITION OF COPPER-ZINC ALLOYS—*Continued.*

II. *Brass and Similar Alloys.*

Name.	Copper	Zinc.	Tin.	Lead.	Various metals.
Sheet brass from Stollberg.....	64.8	32.8	0.4	2.0	
" " Hegermühle..	70.16	27.45	0.2	0.79	
" " Ocker.....	68.98	29.54	....	0.97	0.79 antimony. 0.23 iron.
" " Iserlohn.....	70.1	29.9			
" " Lüdenscheid...	72.73	27.27			
" " Vienna	68.1	31.9			
" " Jemappes.....	64.4	33.7	0.2	1.4	
" " China	56.6	38.2	3.3	1.0	1.4 iron.
" for ships' sheathing, so-called Muntz metal.....	60	40			
Brass wire from England.....	70.3	29.2	0.2	0.3	
" " Augsburg.....	71.89	27.63	....	0.85	
" " Neustadt.....	70.16	27.45	0.79	0.2	
" " "	71.36	28.15			
" " "	71.5	28.5			
" good quality.....	65.4	34.6			
" brittle.....	65.5	32.4	....	2.1	
Cast brass from Ocker.....	71.88	24.42	....	1.09	2.32 iron 1.01 antimony.
" " "	62.2	37.2	....	0.5	0.1 iron.
Clock wheels (Black Forest) ..	60.66	36.88	1.35	....	0.74 iron.
" " " " ..	60.06	31.46	....	0.88	1.43 iron.
Turned castings from Iserlohn..	63.7	33.5	2.5	0.3	
" " " " ..	64.5	32.4	0.2	2.9	
Cast brass for stamps used for gilding in book-binderies....	61.6	35.5	....	....	3.0 antimony.
Brass from Lüdenscheid.....	72.73	27.27			
" " "	66.6	33.4			
Aich or sterro-metal malleable in the heat.....	60	38.2	....	....	1.8 iron.
Chrysorin, for fancy articles....	72	28			
" (by Rauchenberger).	66.7	33.3			
Potin, brittle, ordinary brass....	71.9	24.9	1.2	2.0	
English sterling metal.....	66.2	33.1	....	....	0.7 iron.
Thurston's tough, strong brass...	55	44.5	0.5		
Brass, very tenacious (Storer)..	54	46			
" " " " ..	54.9	45.1			
Bristol brass (Prince's metal)..	75.5	24.5			
" " " " ..	67.2	32.8			
" " " " ..	60.8	39.2			
Mosaic gold.....	65.3	34.7			

COMPOSITION OF COPPER-ZINC ALLOYS—*Continued.*

II. *Brass and Similar Alloys.*

Name.	Copper	Zinc.	Tin.	Lead.	Various metals.
Sheet from manganese bronze, pale yellow	60.95	29.93	....	....	1.13 iron. 7.95 manganese
Sheet from manganese bronze, still paler	63.16	26.11	....	...	4.48 manganese 0.74 iron. 3.67 nickel.
Cast brass, French, for fine castin's	63.70	33.55	2.50	0.25	
" " " "	64.45	32.44	0.25	2.86	
" " " "	70.90	24 05	2.00	3.05	
" " " "	72.43	22.75	1.87	2.95	
Robierre's metal, for ship sheathing	66	34			
Sterro-metal (Rosthorn's)	55.33	41.80	....	....	4.66 iron.
" (English or Gedge's alloy for ship-sheathing)	60	38.5	....	...	1.5 iron.

Alloys of Copper with Silver and Gold.—On account of their great intrinsic value these alloys are chiefly used for coinage and in art industries. At the present time the fineness of all coins is determined by thousandths, the standard varying according to the size of the coins, and the laws of the different countries from $\frac{900}{1000}$ to $\frac{750}{1000}$. The fineness used in the manufacture of silverware varies from $\frac{750}{1000}$ to $\frac{950}{1000}$, while that of goldware varies from $\frac{130}{1000}$ to $\frac{950}{1000}$, ordinary Pforzheim gold articles containing, for instance, only from $\frac{130}{1000}$ to $\frac{250}{1000}$.

Color of Gold Alloys.—The color of gold alloys depends on the greater or smaller contents of gold and silver. Alloys very rich in silver are more whitish, and those very rich in copper more reddish. Cadmium imparts a green color, and steel a gray color to the alloy. The following table gives the composition of colored gold alloys most used:

Color.	Parts.				
	Gold.	Silver.	Copper.	Cadmium.	Steel.
Yellow	583	250	167		
Dark yellow	583	125	292		
Very red	583	42	375		
Yellow	666	194	139		
Red	666	67	268		
Yellow	750	146	104		
Red	750	104	146		
Green	750	166	....	84	
"	746	114	97	43	
"	750	125	....	125	
Gray	800	....	....	....	200
"	725	275			
"	857	86	....	....	57
Blue	250 to 750	....	....	....	250
Pale yellow	666	333			
Pale red	600	200	200		

Proportion of Various Metals in Gold Alloys used by Jewellers.

Carats.	Parts.			Melts at degrees F.
	Copper.	Silver.	Gold.	
23	½	½	23	2012
22	1	1	22	2009
20	2	2	20	2002
18	3	3	18	1995
15	6	3	15	1992
13	8	3	13	1990
12	8½	3½	12	1987
10	10	4	10	1982
9	10½	4½	9	1979
8	10½	5½	8	1973
7	9	8	7	1960

Argent-Ruolz.—This alloy, also called *argent français*, has the appearance of pure silver but is much cheaper and harder.

According to the quality of the articles, different alloys are used as follows:

	Parts.		
	I.	II.	III.
Silver.....	33	40	20
Copper.....	37 to 42	30 to 40	45 to 55
Nickel.....	25 to 30	20 to 30	25 to 35

Gray Silver (*Japanese Silver*).—In Japan an alloy of equal parts of silver and copper is prepared which acquires a beautiful gray color by boiling in a solution of alum to which sulphate of copper and verdigris are added.

Tiers Argent (*one-third Silver*).—Silver 33.33 parts, aluminium 66.66. Used in Paris for the manufacture of various utensils. It is harder than silver, and stamped and engraved with greater ease than alloys of copper and silver.

Imitation Silver Alloys.—There is a large number of imitation silver alloys which are used as substitutes for many purposes. The composition of a few of them is here given:

Alloy for Spoons.—A beautiful alloy closely resembling silver is obtained by melting together copper, 50 parts; nickel, 25, and zinc, 25.

Alloy resembling Silver.—Copper, 70 parts; manganese, 30; zinc, 20 to 25.

Delalot's Alloy.—Pure copper, 80 parts; manganese, 2; zinc, 18; phosphate of lime, 1. First melt the copper, then add gradually the manganese and, when this is completely dissolved, the phosphate of lime. Remove the scoria and about ten minutes before casting add the zinc. To promote the fusion of the manganese, ½ part of calcium fluoride, ½ part of borax and 1 part of charcoal may be added.

Mousset's Silver Alloy.—Copper, 59.06 parts; silver, 27.56; zinc, 9.57; nickel, 3.42. Color, yellowish with a reddish tinge, but white upon the fractured surface.

Warne's Metal.—Tin, 10 parts; nickel, 7; bismuth, 7; cobalt, 3. White, fine-grained, quite difficult to fuse.

White Alloy Closely Resembling Silver.—Copper, 69.8 parts; nickel, 19.8; zinc, 5.5; cadmium, 4.7.

Aluminium Alloys. 1. *Aluminium Brasses.*—By this name are generally known the alloys of aluminium with zinc and copper; they are about as much superior to ordinary brass as aluminium bronze is to ordinary bronze. They are made in two general ways; either by introducing metallic aluminium into melted brass or by introducing zinc into melted aluminium bronze. Repeated remeltings of aluminium brass are not advisable, since, like all brasses, it changes its composition on melting, though not to so large a degree. After mixing it needs to be remelted only once in a clean crucible. Aluminium brasses flow well, give sharp sound castings, are more ductile, malleable, and have greatly increased strength and power to resist corrosion.

Cowles Bros. report the following series of tests made, in 1886, at their works in Lockport, their alloys all being made by adding zinc to aluminium bronze:

Composition.			Tensile strength per square inch (castings).	Elongation per cent.
Aluminium.	Copper.	Zinc.		
5.8	67.4	26.8	95.712	1.0
3.3	63.3	33.3	85.867	7.6
3.0	67.0	30.0	67.341	12.5
1.5	77.5	21.0	32.356	41.7
1.5	71.0	27.5	41.952	27.0
1.25	70.0	28.0	35.059	25.0
2.5	70.0	27.5	40.982	28.0
1.0	57.0	42.0	68.218	2.0
1.15	55.8	48.0	69.520	4.0

When it is remembered that ordinary brass has rarely a tensile strength of over 30,000 lbs. with an elongation of about 10 per cent., the benefit of the aluminium can be easily realized. The principal disadvantage of aluminium brass compared with alumin-

ium bronze is that it cannot be remelted without changing its quality by reason of its containing zinc.

2. *Aluminium Bronze.*—Aluminium possesses properties which render it one of the most useful metals yet discovered, and the only bar to its greater employment has hitherto been its high price. At the present time strenuous efforts are made to cheapen the manufacture of the metal, and there is an immediate prospect of the price being considerably reduced by various new processes. While being very malleable and ductile, aluminium ranks second only to steel in tenacity; it is highly sonorous, four times lighter than silver, non-volatile at very high temperatures, conducts heat and electricity as well as silver, is inoxidizable in the air even at a red heat, is not acted upon by water, sulphuretted hydrogen or ammonium sulphide, resists concentrated nitric acid and dilute sulphuric acid, and forms alloys of considerable value.

The alloys of aluminium with copper show very different properties according to the quantities of aluminium they contain. Alloys containing but little copper cannot be used for industrial purposes. With 60 to 70 per cent. of aluminium they are very brittle, glass-hard and beautifully crystalline. With 50 per cent. the alloy is quite soft, but under 30 per cent. of aluminium the hardness returns.

The usual alloys are those of 1, 2, 5 and 10 per cent. of aluminium. The 5 per cent. bronze is golden in color, polishes well, casts beautifully, is very malleable, cold or hot, and has great strength, especially after hammering. The 7.5 per cent. bronze is to be recommended as superior to the 5 per cent. bronze. It has a peculiar greenish-gold color which makes it very suitable for decoration. All these good qualities are possessed by the 10 per cent. bronze. It is bright golden, keeps its polish in the air, may be easily engraved, shows an elasticity much greater than steel, and can be soldered with hard solder.

In making aluminium-copper alloys great attention must be paid to the quality of the copper used. Ordinary commercial copper may contain small amounts of antimony, arsenic or iron, which the aluminium can in no way remove and which effect very injuriously

the quality of the bronze. The aluminium bronzes seem to be extremely sensitive to the above metals, particularly to iron. This necessitates the employment of the purest copper; electrolytic is sometimes used when not too high-priced, but Lake Superior is generally found satisfactory enough. Even the purest copper may contain dissolved cuprous oxide or occluded gases, and it is one of the functions of aluminium to reduce these oxides and gases, forming slag which rises to the surface and leaving the bronze free from their influences. If tin occurs in the copper it lowers very greatly the ductility and strength of the bronzes, but zinc is not so harmful.

Care should also be taken as to the purity of the aluminium used, though its impurities are not so harmful as they would be if occurring in similar percentage in copper, since so much more copper than aluminium is used in these alloys. Yet the bronzes are so sensitive to the presence of iron that an aluminium with as small a percentage of this metal as possible should be used. The silicon in commercial aluminium is not so harmful as the iron, but it does harden the bronze considerably and increases its tensile strength. The purest aluminium alloyed with the purest copper always produces the highest quality of bronze.

The following directions for preparing the bronzes are given: Melt the copper in a plumbago crucible and heat it somewhat hotter than its melting point. When quite fluid and the surface clean, sticks of aluminium of a suitable size are taken in tongs and pushed down under the surface, thus protecting the aluminium from oxidization. The first effect is necessarily to chill the copper more or less in contact with the aluminium, but if the copper was at a good heat to start with, the chilled part is speedily dissolved and the aluminium attacked. The chemical action of the aluminium is then shown by a rise of temperature, which may even reach a white heat. Considerable commotion may take place at first, but this gradually subsides. When the required amount of aluminium has been introduced, the bronze is let stand for a few minutes and then well stirred, taking care not to rub or scrape the sides of the crucible. By the stirring the slag, which commences to rise even

during the alloying, is brought almost entirely to the surface. The crucible is then taken out of the furnace, the slag removed from the surface with a skimmer, the melt again stirred to bring up what little slag may still remain in it, and is then ready for casting. It is very injurious to leave it longer in the fire than is absolutely necessary. No flux is necessary, the bronze needing only to be covered with charcoal powder. The particular point to be attended to in melting these bronzes is to handle as quickly as possible when once melted.

As with ordinary brass and bronze two or three remeltings are needed before the combination of the metal appears to be perfect and the bronze takes on its best qualities. After three or four meltings it reaches a maximum at which point it may be melted several times without sensible change. It gives good castings of all sizes and runs in sand moulds very uniformly. Its specific gravity is 7.68, about that of soft iron. Its strength when hammered is equal to the best steel. It may be forged at about the same heat as cast-steel and then hammered until it is almost cold without breaking or ripping. Tempering makes it soft and malleable. It does not foul a file and may be drawn into wire. Any part of a machine which is usually made of steel can be replaced by aluminium bronze.

Ferro-aluminium.—The iron-aluminium alloy known by this name, which is being largely used at present for introducing into iron and steel, is generally made with 5 to 15 per cent. of aluminium. Several different makes of this alloy are on the market, some made directly from alumina, others made by adding aluminium to iron. When made by the latter method a good quality of pig-iron is chosen, and when melted the aluminium, in bars, is seized in tongs and dipped under the surface. A rise of temperature occurs, and a noticeable separation of graphitic carbon, causing "kish" to collect on the surface. It is said that the pig-iron thus alloyed has its combined carbon almost entirely converted into free carbon, losing thereby in weight sometimes as much as 2½ per cent. When all the aluminium required has been added the melt is stirred, the crucible remaining in the fur-

nace; then it is let stand for a few minutes, taken out of the fire, skimmed clean and cast into slabs or bars.

Various Aluminium Alloys.—The following alloys have been patented by Mr. Jas. Webster:

I. Copper is melted and aluminium added to it until a 10 per cent. bronze is made. There is then added to it 1 to 6 per cent. of an alloy, ready prepared, containing: Copper, 20 parts; nickel, 20; tin, 30; aluminium, 7.

II. The two following alloys are prepared in the usual way, under a flux consisting of equal parts of potassium and sodium chlorides, and are cast into bars.

I.		II.	
Aluminium	15 parts.	Nickel	17 parts.
Tin	85 "	Copper	17 "
		Tin	100 "

To make the bronzes equal parts of these two alloys are melted with copper, the more of the alloys used the harder and better the bronze. The best mixture is, of copper, 84 parts; alloy I., 8; alloy II., 8. The copper is first melted, then the alloys put in together and stirred well with a stirrer of wood or clay. This alloy is suitable for art castings, kitchen utensils, etc., or anywhere where durability, hardness, malleability, polish and very slight oxidizability are required. A cheaper and more common alloy may be made of copper, 91 parts; alloy I., 4; alloy II., 5.

III. The following alloy is said to withstand oxidation well, to have great tenacity, durability, capability to bear vibrations and to take a high polish. A preliminary alloy is made of copper, 200 parts; tin, 80; bismuth, 10; aluminium, 10. The alloy proper is formed by melting together: Preliminary alloy, 4½ parts; copper, 164; nickel, 70; zinc, 61½.

IV. Copper, 53 parts; nickel, 22½; zinc, 22; tin, 5: bismuth, ¾; aluminium, ¾.

Alloy for Dental Plates.—Aluminium, 90 to 93 parts; silver, 5 to 9; copper, 1. This alloy, when cast under slight pressure, gives perfect castings, is very white and easy to work. The addition of

copper is said to decrease to a minimum the shrinkage of the alloy, also giving a closer grain.

Alloy Resembling German Silver.—Copper, 70 parts; nickel, 23; aluminium, 7. This alloy has a beautiful white color and takes a high polish. It resembles some of the finer grades of German silver.

Alloy Resembling Silver.—Copper, 75 parts; nickel, 16; zinc, 2¼; tin, 2¾; cobalt, 2; iron, 1½; aluminium, ½.

Bourbonne's Aluminium Alloy.—For many purposes this alloy may serve as a substitute for aluminium. It is obtained by melting together 10 parts of tin and 10 of aluminium. It is whiter than aluminium, has a specific gravity of 2.05 (is, therefore, somewhat heavier than the pure metal), is more capable than aluminium of resisting most agents and is worked with greater ease. Finally the alloy, without previous preparation, can be soldered as readily as brass.

Lechesne.—Under this name two compositions have been patented in England:

	I.	II.
Copper	900 parts.	600 parts.
Nickel	100 "	400 "
Aluminium	1¾ "	½ "

The first of these alloys is the one to which the name "Lechesne" appears to be given. It is made by putting first the nickel into the crucible and after melting gradually stirring in the copper. The heat is then raised and the aluminium added. The alloy is heated almost to boiling and cast very hot. It is claimed that this alloy is equal to the finest German silver.

Minargent.—Copper, 100 parts; nickel, 70; antimony, 5; aluminium, 2. It is similar to the alloy resembling German silver, but somewhat harder. Melt together the copper, nickel and antimony, and then granulate the resulting alloy in water. The dried granules are mixed with the aluminium and with 1.5 per cent. of a flux consisting of 2 parts borax and 1 part fluorspar, and then remelted.

Neogen.—Copper, 58 parts; zinc, 27; nickel, 12; tin, 2; bis-

muth, ½; aluminium, ½. This alloy is claimed to closely resemble silver.

Nürnberg Gold.—Copper, 90 per cent.; gold, 2½; aluminium, 7½. This alloy is used for making cheap imitation gold ware, resembling gold in color and not tarnishing in the air.

Britannia Metal and Similar Alloys.—These alloys are of great importance. They are readily fusible and very useful for cheap ware, which may frequently be silvered. Britannia metal consists principally of tin alloyed with antimony. Many varieties contain only these two metals and may be considered as tin hardened by antimony. Other similar alloys contain, however, in addition, certain quantities of copper, sometimes lead, and occasionally bismuth.

The following table shows the composition of several varieties of Britannia metal:

Britannia metal.	Parts.					
	Tin.	Antimony.	Copper	Zinc.	Lead.	Bismuth.
English	81.9	16.25	1.84			
"	90.62	7.81	1.46			
"	90.1	6.3	3.1	0.5		
"	85.4	9.66	0.81	3.06		
Pewter	81.2	5.7	1.6	....	1.15	
"	89.3	7.6	1.8	....	1.8	
"	83.3	6.6	1.6	3.06	....	1.6
Tutania	91.4	....	0.7	0.3	7.6	
Queen's metal	88.5	7.1	3.5	0.9		
German	72	24	4			
"	84	9	2	5		
" (cast)	20	64	10	6		
Malleable (cast)	48	....	3	48	....	1
Birmingham (sheet)	90.6	7.8	1.5			
" (cast)	90.71	9.2	0.09			
Karmarsch's	85	5	3.6	1.4	....	1.6
Keller's	85.7	10.4	1	....	....	1.8
Wagner's (fine)	85.64	9.66	0.81	3.06	....	0.83

Ashberry Metal.—Copper, 2 parts; tin, 80; antimony, 14;

zinc, 1 ; nickel, 2 ; aluminium, 1. *Or* copper, 3 parts ; tin, 79 ; antimony, 15 ; zinc, 2 ; nickel, 1. Used for coffee-pots, tea-pots and all similar articles generally made of Britannia metal.

Biddery Metal.—Genuine East India Biddery metal consists of copper, 3.5 parts ; zinc, 93.4 ; lead, 3.1. *Or* copper, 11.4 parts ; zinc, 84.3 ; tin, 1.4 ; lead, 2.9.

Minofor Metal.—Copper, 3.26 parts ; tin, 67.53 ; antimony, 17 ; zinc, 8.94. *Or* copper, 4 parts ; tin, 66 ; antimony, 20 ; zinc, 9 ; iron, 1. Used for the same purposes as Britannia metal.

Manganese Alloys.—A favorable effect is produced by an addition of manganese to bronze, brass, copper, etc. All varieties of commercial copper, as well as bronzes, contain more or less oxide, which injures the properties of these alloys, especially decreasing their tenacity and malleability. The removal of such admixtures of oxide is effected by substances which have a greater affinity for oxygen than copper, for instance, by an addition of phosphorus in the preparation of phosphor-bronze. Metallic manganese acts, however, far more energetically, as it does not volatilize like phosphorus at the fusing temperature. For this purpose an alloy of copper and manganese, the so-called *cupro-manganese*, consisting of copper, 70.5 parts ; manganese, 25, and coal, 0.5, is recommended. Of this composition an addition of 2⅔ per cent. suffices for most cases. The process is very simple. After melting the bronze masses the metal-bath is covered with pulverized wood charcoal, and the pieces of cupro-manganese previously weighed and reduced to small pieces are allowed slowly to slide into the crucible. Fusion takes place instantaneously, but the crucible is for a few moments to be replaced upon the fire in order to somewhat increase the temperature reduced by the addition of the cold pieces of metal. In pouring out proceed in the ordinary manner. To enclose the oxide of manganese formed by this process add to the charcoal with which the metal-bath is covered about one-half its quantity of pure carbonate of soda or potash. The following alloys are prepared according to this method :

I. Tin, 16 parts ; zinc, 3½ ; lead, 3½ ; cupro-manganese, 1.

II. Tin, 16 ; zinc, 3 ; lead, 3 ; cupro-manganese, 2.

III. *Red Brass.*—Copper, 85; tin, 14; cupro-manganese, 1. *Or* copper, 81; tin, 17; cupro-manganese, 2.

IV. *White Metal.*—Tin, 42; lead, 40; antimony, 20; cupro-manganese, 2.

Ferro-manganese.—This is composed of manganese, 75 parts, and iron, 75, and may be used for the preparation of sterro-metal: copper, 54 parts; zinc, 40; ferro-manganese, 6.

A composition of cupro-manganese, consisting of copper, 70 per cent., and manganese, 30 per cent., is used as an addition to many alloys, especially for tombac, brass and bronze. By this addition greater density, solidity and extensibility are imparted to the alloys. A copper-tin alloy with 6 per cent. manganese possesses the hardness of steel. For *bearings* the alloy consists of copper, 80 parts; tin, 6; zinc, 5; cupro-manganese, 9. For *rolls* an alloy composed of tin, 64 parts; copper, 8; antimony, 16; lead, 10; and cupro-manganese, 2, is recommended. For *malleable brass*, copper, 56½ parts; zinc, 42; and cupro-manganese, 1½.

Manganese alloys are capable of taking a good polish and have a white to rose-color color. Cupro-manganese is used in refining copper for the reduction of cuprous oxide, the manganese alloy playing in this case a role corresponding to that of ferro-manganese in the preparation of steel.

Manganese Silver consists of copper, 80 per cent.; manganese, 15; and zinc, 5. It is white, takes a good polish and is readily worked.

Manganese Steel.—To the steel melting quietly 80 per cent. ferro-manganese is added in such quantity as desired. The steel is then poured out. To obtain steel with 9 per cent. manganese 0.11 to 0.12 per cent. of the 80 per cent. ferro-manganese, together with 5.5 to 6 per cent. of carbon, have to be added. This steel mixture liquefies with ease. The pieces prepared from it are very resistant to shocks. It is difficult to work with drill or chisel, but can be conveniently hammered and stretched.

Hadfield's Manganese Steel.—The electrical resistance of the non-magnetic manganese steel is 8 times greater than that of ordinary steel and iron and 30 times greater than that of copper. Material

with 5 or 6 per cent. of manganese is very hard; with 10 per cent., soft; with 22 per cent., hard. For wrought material the best content is 14 per cent., with not over 1 per cent. of carbon. In France manganese steel is used for horse-shoes, whole regiments of cavalry being provided with them.

Nickel Alloys.—1. *Nickel and Copper.* Nickel and copper unite in a wide range of proportions, the color of the alloys varying from copper-red to the blue-white of the nickel. The use of alloys of copper and nickel alone is limited; they are chiefly employed for coinage, the beautiful white color and considerable hardness imparted to copper by an addition of nickel making them especially suitable for this purpose.

Nickel Coins of the United States, Belgium and Brazil.—Copper, 75 parts; nickel, 25.

2. *Nickel, Copper and Zinc Alloys.*—These alloys form the mixtures of metals known as German silver, packfong, *argent neuf*, etc. The preparation of German silver must be executed with the greatest care, since nickel has a very high melting point. The more readily fusible metals are first melted and alloyed together, after which the fused nickel is brought into the crucible and the whole vigorously stirred with a stout wooden stick.

The following table gives the composition of various kinds of German silver;

	Parts.				
	Copper	Zinc.	Nickel	Lead.	Iron.
French for sheet	50	31.3	18.7		
	50	30	20		
	58.3	25	16.7		
Vienna	50	25	25		
	55.6	22	22		
	60	20	20		
Berlin	54	28	18		
	55.5	29.1	17.5		
English	63.34	17.01	19.13		
	62.40	22.15	15.05		
	62.43	26.05	10.85		

Various kinds of German Silver

	Parts.				
	Copper	Zinc.	Nickel	Lead.	Iron.
English	57.40	25	13	....	3
Chinese	26.3	36.8	36.8		
	43.8	40.6	15.6		
	45.7	36.9	17.9		
	40.4	25.4	31.6	....	2.60
For casting	48.5	24.3	24.3	2.9	
	54.5	21.8	21.8	1.9	
	58.3	19.4	19.4	2.9	
	57.8	27.1	14.3	0.8	
	57	20.0	20	3	
Sheffield—					
Common (yellow)	59.3	25.9	14.8		
Silver-white	55 2	24.1	20.7		
Electrum (bluish)	51.6	22.6	25.8		
Hard (can be worked cold)	45.7	20	31.3		
Fricke's—					
Bluish-yellow (hard)	55.5	39	5.5		
Pale yellow (ductile)	62.5	31 2	6.3		
Silvery (hard)	50	18.8	31.2		
" (harder)	59	30	10		
Common formula	55	25	20		

Many varieties of German silver contain different quantities of iron, manganese, tin or very frequently lead to change the properties of the alloy or to cheapen it. An addition of lead makes German silver more fusible; one of tin acts in a certain sense as in bronze, making the alloy denser and more sonorous and causing it to take a better polish. An addition of iron or manganese increases the white color of the alloy, but also renders it more refractory and inclining it towards brittleness.

Alfénide, Argiroide and Allied Alloys.—The alloys brought into commerce under these and many other names consist in most cases of a mixture of metals closely resembling German silver; they are, however, generally electro-plated with pure silver.

Albata Metal.—Nickel, 3 to 4 parts; copper, 20; zinc, 16. Used for plated goods.

Alféniде.—Copper, 59.6 parts; zinc, 30.3; nickel, 10.1; and a trace of iron.

British Plate Metal.—Copper, 20 parts; nickel, 5 to 6; zinc, 8 to 10. Used for plated goods.

Metal for Spoons, Forks, etc.—Copper, 69.8 parts; nickel, 19.8; zinc, 5.5; cadmium, 4.7.

White Alloy Resisting the Action of Vegetable Acids.—Tin, 875 parts; nickel, 55; antimony, 50; bismuth, 20.

White Argentan.—Copper, 8 parts; nickel, 3; zinc, 35. This beautiful composition is a deceptive imitation of silver.

3. *Alloys of Nickel and Steel.*—The composition of the alloy can be as effectually controlled in the open hearth furnace as in the crucible. It can be made in any good open hearth furnace working at a fairly good heat. If the charge be properly worked, nearly all the nickel will be found in the steel; almost nothing being lost in the slag. The ingots are clean and smooth in appearance on the outside, but those richest in nickel are a little more "piped" than ingots of ordinary mild steel. Any scrap produced can be remelted in making another charge without loss of nickel. No extraordinary care is required when reheating the ingots for hammering or rolling. If the steel has been properly made and be of correct composition it will hammer and roll well whether it contains little or much nickel. Tests of steel with varying contents of nickel showed that the addition of 4 per cent. of nickel raises the elastic limit from 16 up to 28 tons, and the breaking strain from 30 up to 40.6 tons without impairing the elongation or contraction of area to any noticeable extent. In another case somewhat similar results were found with an addition of only 3 per cent. of nickel, combined with an increase of the carbon to 0.35 per cent. In two cases, one containing 2.0 per cent. of nickel, 0.90 per cent. of carbon and 0.50 per cent. of manganese, the other 4 per cent. of nickel, 0.85 of carbon and 0.50 of manganese, there was an extreme hardness due in part to the large quantity of carbon present, but also to the presence of nickel in addition.

The quality of hardness obtains as the nickel is increased until about 20 per cent. is reached, when a change takes place, and successive additions of nickel tend to make the steel softer and more ductile, and even to neutralize the influence of carbon. In the 25 per cent. nickel steel there are some peculiar and remarkable properties. In the unannealed specimen the breaking strain is high and the elastic limits moderately so, but in the annealed piece, while the breaking strain remains good, the elastic limit is very greatly reduced, down to one-third of the breaking strain. Again, in both cases, the ductility as shown by the extension before fracture is marvellous, reaching 40 per cent. in 8 inches. Another feature is that this elongation is nearly uniform throughout the piece. The whole of the series of nickel steels up to 50 per cent. nickel take a good polish and finish, with a good surface, the color being lighter with the increased additions of nickel. The steels rich in nickel are practically non-corrodible, and those poor in nickel are much better than other steels in this respect. The 1 per cent. nickel steel welds fairly well, but this quality deteriorates with each addition of nickel. The 25 per cent. nickel steel, with its peculiar properties of high breaking strain, great ductility and comparatively low elastic limit, is extremely well adapted for all operations involving considerable deformation; for instance, for deep stamping and flanging, whilst its non-corrodibility will render it invaluable for a great number of purposes. In the region between 25 per cent. and about 5 per cent. of nickel are an abundance of possibilities as yet comparatively unknown, in which will no doubt be found materials for tool steel equal, if not superior, to anything at present known.

Type Metal.—An alloy of lead and antimony answers best for this purpose. At present a great many receipts for type metal are known, in the preparation of which other metals besides lead and antimony are used for the purpose of rendering the alloy more fusible.

In the following table some alloys suitable for casting type are given:

	Parts.									
	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.
Lead	3	5	10	10	70	60	55	55	100	6
Antimony	1	1	1	2	18	20	25	30	30	
Copper	....	....	....	....	2	....	....	....	8	4
Bismuth	....	....	....	1	....	....	....	....	2	
Zinc	....	....	....	....	....	....	....	....	....	90
Tin	....	....	....	....	10	20	20	15	20	
Nickel	....	....	....	....	....	...	....	....	8	

Ehrhardt's Type Metal is composed of zinc, 89 parts; tin, 4; lead, 3; copper, 4; *or*, zinc, 93; tin, 3; lead, 3; copper, 2.

Music Plates.—I. Tin, 5 to 7.5 parts; antimony, 5 to 2.5. II. Lead, 16; antimony, 1. III. Lead, 8; antimony, 2; tin, 1.5. IV. Lead, 4; antimony, 2; zinc, 1. V. Lead, 7.5; antimony, 2.5; copper, 0.5.

Various Alloys.—Acid-proof Bronze. This alloy may be advantageously substituted for hard rubber, porcelain and other substances which, though acid-proof, are much exposed to wear and tear, and sometimes too costly. The alloy consists of copper, 15 parts; tin, 2.34; lead, 1.82; antimony, 1. The metals are melted together in the usual manner, and the alloy is worked like ordinary bronze.

Alloy for Casting Small Articles.—Fuse a mixture of 79 per cent. of cast-iron, 19.50 of tin and 1.50 of lead. This alloy has a beautiful appearance, and fills the mould completely. It is to a certain extent malleable.

Alloy for Moulds for Pressed Glass.—An alloy suitable for this purpose is obtained by melting together 100 parts of iron with 10 to 25 of nickel.

Alloy of Copper and Antimony.—A beautiful alloy is produced by fusing together in a crucible at a strong heat equal parts of antimony and copper. The compound is hard and of a beautiful violet hue. This alloy has not yet been applied to any useful

purpose, but its excellent qualities, independent of its color, entitle it to consideration.

Alloys for Calico-printing Rollers.—Hauvel considers a semi-hard bronze of the following composition the best material for the rollers: Copper, 86 parts; tin, 14; zinc, 2. Rendel, on the other hand, found an English roller material composed of copper, 5.6 parts; zinc, 78.3; tin, 15.8. Though this compound gives a hard, fine-grained alloy, it is likely to be readily attacked by the colors used in printing.

According to analyses by J. Dépierre and P. Spiral, the composition of the scrapers (sometimes called doctors or ductors) intended to remove the surplus of colors from the rollers is as follows:

	Copper.	Zinc.	Tin.
Yellow French scrapers.....	78.75	12.50	8.75
" English "	80.50	10.50	8.00
" German "	85.80	9.80	4.90

Alloys for Small Patterns in Foundries.—I. Tin, 7.5 parts; lead, 2.5. II. Zinc, 75 parts; tin, 25. III. Tin, 30 parts; lead, 70. The last of these alloys is for patterns which will not be in frequent use, and which may be mended, bent, etc. The first gives harder and stiffer patterns; the second is harder than tin and more tenacious than zinc, while at the same time it preserves a certain ductility.

Birmingham Platinum.—This is a white alloy for buttons, and consists of copper, 43 per cent.; zinc, 57. Other alloys for white buttons are: I. Yellow brass, 32 parts; zinc, 3; tin, 1. II. Yellow brass, 32 parts; zinc, 4; tin, 2.

Calin.—By this name is known an alloy used by the Chinese for lining tea-chests. It is composed of lead, 126 parts; tin, 17.5; copper, 1.25, and a trace of zinc.

Cooper's Alloy for Steel-pens.—Copper, 1 part; platinum, 4; silver, 8. It is distinguished by its hardness, elasticity and incorrodibility.

Dysiot.—By this name is known a bearing-metal manufactured

by Rompel & Co., of Homburg. It is prepared by melting together copper, 62 parts; lead, 18; tin, 10; and zinc, 10.

Fahlun or Tin Brilliants.—An alloy of especially fine lustre is known under the name of "Fahlun brilliants." It is used for stage jewelry and consists of tin, 3 parts, and lead, 2, or of tin, 3 parts, and lead, 1. For the production of brilliants melt small portions of the alloy in an iron crucible. By dipping into the fluid mass, previously freed from every particle of oxide, pieces of glass or brass, ground like brilliants and highly polished, a thin layer of metal adheres to them which, after cooling, can be readily detached. The separate pieces may be connected by soldering. Sometimes the alloy is poured into moulds faceted in the same manner as diamonds.

Gold and Palladium Alloys.—Alloys of gold, copper, silver and palladium have a brownish-red color, and the hardness of iron. They are sometimes used for bearings of the arbors in fine watches, as they cause but little friction (less than the jewels used for the same purpose) and never rust on exposure to the air. The composition used in the Swiss and English watch factories consists of gold, 18 parts; copper, 13; silver, 11; palladium, 6.

Gold-like Alloy.—This alloy closely resembling gold is obtained by melting together copper, 16 parts; zinc, 1; and platinum, 7. The copper and platinum are first covered with borax, next with pulverized charcoal, and melted, after which the zinc is added. The alloy produced is easily worked and may be drawn into the finest wire; it does not turn blue.

Iron Alloy.—A compact, very malleable iron alloy capable of taking a high polish has been patented in England, by W. M. Arnold. It is obtained by melting together pig-iron, 50 lbs.; sodium, ½ lb.; copper and antimony, each ¼ lb., and zinc 2½ lbs. It is claimed to be especially suitable for ships' screws, it resisting quite well the corroding action of sea-water. By omitting the sodium and decreasing the quantity of zinc a softer variety of iron is obtained, while the additions of larger quantities of sodium and zinc and the decrease of the content of copper yield a harder material.

Lemarquand's Non-oxidizable Alloy.—Copper, 750 parts; nickel, 140; black oxide of cobalt, 20; tin in sticks, 18; zinc, 72. The metals must be pure.

Lutecine or Paris Metal.—Copper, 800 parts; nickel, 160; tin, 20; cobalt, 10; iron, 5; and zinc, 5.

Malleable Brass.—Alloy, copper, 33 parts, and zinc, 25 parts, the copper being loosely covered with the zinc in the crucible. As soon as the copper is melted pure zinc is added. The alloy is then cast in molding sand into the shape of bars, which, it is said, are malleable into any form when still hot. To make brass soft, heat it to a low red and plunge in water. It cannot be hardened except by rolling and hammering.

Marley's Non-oxidizable Alloy.—Iron, 10 parts; nickel, 35; brass, 25; tin, 20; zinc, 10. Articles prepared from this alloy are heated to a white heat and dipped into a mixture of sulphuric acid, 60 parts; nitric acid, 10; hydrochloric acid, 5; and water, 25.

New Alloys.—I. An alloy which is said to practically resist the attack of most acid and alkaline solutions is composed as follows: Copper, 15 parts; tin, 2.34; lead, 1.82; antimony, 1. This alloy is, therefore, a bronze with the addition of lead and antimony. It is claimed that it can be very advantageously used in the laboratory to replace vessels or fittings of ebonite, vulcanite or porcelain.

II. Pure copper or tin is melted and to the melted mass is added a piece of arsenic enclosed in a copper capsule. After thorough stirring the mass is granulated by pouring into water. The granules of the alloy thus obtained are remelted and then used as an addition for the preparation of bronze and other alloys, whereby it is claimed the alloy acquires greater elasticity, strength and homogeneity than phosphor-bronze and similar alloys.

III. *For the Manufacture of Jewelry, etc.*—This alloy has a color resembling that of the various alloys of gold. It is very resistible and ductile and acquires great lustre by polishing. It consists of 978 parts by weight of pure copper; 2 of gold; and 20 of aluminium. The copper and gold are first melted in a crucible

of chamotte * or other refractory material, and when the metals are fluid the aluminium is added. When not more than 2 lbs. of the alloy are made at one time the mass is kept in a fused state for half an hour, about 1¾ ozs. of borax being added as a flux. The melted mass is then poured into ingots. The alloy thus obtained can be worked into sheet, wire or ribbon, as required for the manufacture of jewelry. To obtain the various colors it is only necessary to vary the proportions of the three metals; for red, for instance, somewhat less gold and aluminium is used, for yellow somewhat less gold, and for green somewhat less gold and more aluminium.

New Imitations of Gold and Silver.—To prepare an alloy having the appearance and color of gold, melt in a crucible 800 parts by weight of pure copper, 25 of platinum, and 10 of tungstate of lime, and granulate the melt by letting it run into water containing for every 35.31 cubic feet 17 ozs. each of slaked lime and potash. The purpose of these ingredients is to purify the alloy. The metallic granules are then collected and dried, and after remelting them in the crucible, 170 parts by weight of gold are added. This alloy, when cast into ingots, has the appearance of red gold. Different colors may be obtained by varying the proportions of the metals. Boric acid, saltpetre, and sodium chloride, previously fused together in equal proportions, are used as flux; the proportion is 7 drachms to 1 lb. of alloy.

The alloy used for the imitation of silver consists of iron, 65 parts; nickel, 23; tungstate of lime, 4; aluminium, 5; and copper, 5. The iron and tungstate of lime are fused together, and granulated in the same manner as above described, with the exception that the water into which the alloy is allowed to run contains 2 lbs. each of slaked lime and potash to every 35.31 cubic feet. During fusion in the crucible the metals must be carefully covered with a flux consisting of 1 part of boric acid and 1 of potassium nitrate. In the crucible containing the aluminium and the copper place a piece of soda (15 grains to every 10 lbs. of metal), to prevent the

* A mixture of unburnt fire-clay and dust of fire-bricks, glass pots or seggars.

oxidation of the aluminium; add also some charcoal, to prevent the oxidation of the copper. Before granulating the metal, thoroughly stir the contents of each crucible with a ladle of fire-clay. The granulated metal is dried, then melted together in the above-mentioned proportions, thoroughly stirred, and cast into ingots. This alloy has the appearance of silver or of platinum. The alloys resist the action of sulphuretted hydrogen, and are not attacked by vegetable acids and but slightly by mineral acids; they are ductile and flexible.

New Method of preparing Alloys.—The alloys consist of heavy metals and the sulphides of the alkali metals, or metals of the alkaline earths. Preferably sulphide of strontium is alloyed with copper, in order to obtain a product of a constant gold-like color. For this purpose zinc is melted together with 8 to 15 per cent. of calcined strontium sulphate, and the resulting alloy allowed to cool. To this alloy a varying quantity of copper is added, according to the color and power of resistance required. As much of the zinc as desired may be expelled by subsequent cupellation.

Non-Magnetic Alloys for Watches.—To overcome the injurious effect of magnetic action upon watches, alloys of palladium are proposed as substitutes for steel wherever it is employed in the works. The composition of the new alloys varies from 45 to 75 parts of palladium, 15 to 30 parts of copper, 20 to 25 parts of silver, with sometimes the addition of small proportions of iron, steel, nickel, gold, and platinum. These alloys are claimed to be unoxidizable in moist air, to preserve their elasticity indefinitely, not to vary sensibly with changes of temperature, and remain uninfluenced by proximity to dynamos.

Another non-magnetic alloy, recently brought out by Messrs. Ostermann and Lacroix, of Geneva, Switzerland, is made of from 30 to 40 parts of gold, 30 to 40 parts of palladium, 0.1 to 5 parts of rhodium, 10 to 20 parts of copper, 0.1 to 5 parts of manganese, and the same proportion of silver and platinum. The copper and manganese are first mixed, after which the other articles are added; or all the metals may be put into a crucible at the same time, the manganese being used for the bottom layer.

Non-Oxidizable Alloy.—Iron, 10 parts; nickel, 36; copper, tin, zinc, each, 18. This metal has a white color, with a slightly reddish tinge.

Platinoid.—This alloy is a kind of German silver, with an addition of 1 to 2 per cent. of tungsten. The latter, in the form of phosphor-tungsten, is first melted together with a certain quantity of copper, the nickel is next added, then the zinc, and finally the remainder of copper. In order to remove the phosphorus and a portion of the tungsten, both of which separate dross, the resulting compound is several times remelted. Finally an alloy of a beautiful white color is obtained, which, when polished, closely resembles silver, and retains its lustre for a long time. Platinoid has the properties of German silver in a pre-eminent degree. It shows great resistance, which remains quite constant at different temperatures, and is about 1½ times greater than that of German silver.

Platinum Bronze.—This name is applied to an alloy prepared from 100 parts of pure nickel, 10 of tin, and 1 of platinum, by adding to the melted nickel the platinum and 4 parts of the tin, and then gradually the remaining 6 parts of tin. This alloy is intended for household utensils. For bells, etc., 100 parts of nickel, 20 of tin, 2 of silver, and 1 of platinum are used.

Shakdo.—This is a Japanese alloy, consisting of copper and gold, the proportion of the latter varying from 1 to 10 per cent. Articles made from this composition are, after polishing, boiled in a pickle, consisting of cupric sulphate, alum, and verdigris, whereby they acquire a bluish-black color. Shakdo is worked into scabbards, buckles, etc., and into many decorative articles.

Sideraphtite.—This alloy consists of iron, 65 parts; nickel, 23; tungsten, 4; aluminium, 5; and copper, 5. It is claimed to resist the action of vegetable acids, and to be quite indifferent towards mineral acids.

Soft Alloy for Coating Metals, etc.—From a solution of cupric sulphate precipitate the copper with zinc; pulverize the precipitate, and in a porcelain dish make the copper-dust thus obtained into a cake with pure sulphuric acid of 1.85 specific gravity. According to the hardness desired, carefully mix 20, 30, or 36 parts of this

cake with 70 parts of mercury, and wash the amalgam thus obtained with an abundance of warm water to remove all traces of acid. In 10 to 12 hours the alloy is so hard that it will scratch tin. For use heat the alloy until it can be worked like wax. In this state it is applied to the surface of the article, to which, after cooling, it adheres with great tenacity.

II. *Amalgams.*—The readiness with which mercury unites with most of the other metals to form definite chemical compounds, called "amalgams," is one of its most striking properties and is turned to account for the extraction of silver and gold from their ores. Amalgams are crystalline combinations and form at a low temperature. They are at first so soft that they can be kneaded like wax, but after some time harden completely. The following are some of the most important:

Amalgam of Lipowitz's Metal.—This amalgam is prepared as follows: Melt in a dish, cadmium, 3 parts; tin, 4; bismuth, 15, and lead, 8, and add to the melted alloy 2 parts of mercury previously heated to about 212° F. Amalgamation takes place readily and smoothly. After the introduction of the mercury immediately take the dish from the fire and stir the liquid mass until it solidifies. While Lipowitz's alloy becomes soft at 140° F. and melts at 158° F., the amalgam melts at about 143.5° F. This amalgam may be used for the manufacture of small, hollow statuettes and busts, which can be readily gilded or bronzed by the galvanic process.

Small statuettes are readily made by preparing a hollow mould of plaster of Paris and after uniformly heating it to about 140° F. pouring in the melted amalgam. The mould is then swung to and fro, this being continued until the amalgam is solidified. After cooling the mould is taken apart and the seams trimmed with a sharp knife. The operation may also be modified by placing the mould upon a rapidly revolving disk and pouring in the melted amalgam in a thin stream. By the centrifugal force developed the melted metal is hurled against the sides of the mould, and in this manner statuettes of considerable size can be cast.

Copper Amalgam.—Place strips of zinc in a solution of sulphate

of copper and shake vigorously. The copper thus obtained in the form of a delicate powder is washed and while still moist treated in a dish with a solution of mercurous nitrate. Hot water is then poured over the copper, the dish kept warm, and the mercury added. The contents of the dish are then kneaded with a pestle until the pulverulent copper combines with the mercury to a plastic mass. The longer the kneading is continued the more homogeneous the mass will be. The best proportions to use are 3 parts of copper and 7 of mercury.

An important application of copper amalgam is for cementing metal, it being only necessary to apply it to the metals to be cemented, which must be bright and previously heated to from 176° to 194° F., and press them togetner; they will be joined as firmly as if soldered.

A composition of 25 parts of copper in fine powder obtained by precipitation from solutions of the oxide by hydrogen, or the sulphate of zinc, washed with sulphuric acid and amalgamated with 7 parts of mercury, after being well washed and dried, is moderately hard, takes a good polish and makes a fine solder for low temperatures. It will adhere to glass.

An imitation of gold, which, on account of its golden-yellow color and capability for taking a fine polish, is suitable for the manufacture of cheap jewelry, consists of copper, 86.4 parts; mercury, 13.6.

Gold Amalgam.—This is formed when mercury is heated with powdered gold or gold-foil. It consists usually of 2 parts of gold to 1 of mercury. An amalgam suitable for fire-gilding is best prepared as follows: Heat in a graphite crucible, rubbed inside with chalk to prevent adhesion, the gold to be alloyed to a red heat. It is not absolutely necessary to use chemically pure gold, but it should be at least 22 carat fine and preferably alloyed with silver instead of copper. Gold amalgam containing copper becomes stone-hard in a short time, and a small content of it impairs its uniform application to the metals to be gilded. It is best to use the gold in the form of thin sheets, which are cut into small pieces by means of scissors, and brought into the crucible. When the

gold is heated to a red heat introduce about the eighth or ninth part of the weight of the gold of mercury previously heated to boiling. Stir constantly with an iron rod, and after a few minutes remove the crucible from the fire. If the finished amalgam were allowed to cool in the crucible it would become strongly crystalline and be unsuitable for fine gilding. To prevent this it is at once poured into a larger vessel cooled by water. By keeping this amalgam for some time crystallization nevertheless takes place, the amalgam separating from the mercury in excess, and it is, therefore, advisable to prepare it fresh a short time before use. Crystalline amalgam can be restored by heating in a crucible with an excess of mercury.

Iron Amalgam is only used in the industries in rare cases where iron is to be fire-gilt, and then it is produced upon the article to be gilded itself. For this purpose the article previously made bright by pickling is boiled in a mixture of mercury, 12 parts; zinc, 1; copperas, 2; water, 12; hydrochloric acid, 1. The mercury dissolved in the solution separates upon the iron article, a thin, lustrous layer of iron amalgam being formed upon the surface to which the amalgam of gold can be readily and uniformly applied without further preparation.

Silver Amalgam.—This is best prepared by the use of pulverulent silver obtained by the reduction of silver solution. It may be prepared by bringing a solution of nitrate of silver in 10 to 15 parts of water into a bottle, adding a few small pieces of sheet zinc and vigorously shaking for a few minutes. The silver separating in the form of a very fine black-gray powder need only be washed and dried to be suitable for the preparation of amalgam. This finely divided powder may be directly dissolved in the mercury, though it requires some time. The object is more quickly attained by heating the mercury nearly to boiling in a crucible, then throwing in the pulverulent silver and quickly combining the mass by vigorous stirring with an iron rod.

Tin Amalgam.—Tin and mercury combine readily at ordinary temperatures. If 3 parts of mercury are brought into contact with 1 of tin, 6-sided crystals of tin amalgam are formed. Tin amalgam

is used for silvering looking-glasses. When pulverized and rubbed on the polishing-stone it forms a kind of mosaic silver. Electric amalgam may be made by melting tin and zinc together in various proportions in a porcelain crucible. The mixture is well stirred up and when on the point of solidifying the mercury is added and worked into the mass. The whole is next transferred to a mortar warm enough to keep the amalgam soft, while it is well worked together, after which a piece of tallow or lard, not quite the equal in bulk to the mass, is kneaded in until the amalgam attains the proper consistency.

Zinc Amalgam is formed by mixing and triturating zinc filings with mercury at a heat somewhat below the boiling point of the latter. It is usually prepared by pouring mercury into zinc at the temperature at which the latter is just kept in a fused state. Care must be taken to keep the liquid stirred and to add the mercury slowly and in as fine a stream as possible.

V.

ANNEALING, HARDENING, TEMPERING.

Annealing of Hard and Other Iron Castings.—The process consists in the sudden immersion of the casting at a certain temperature into a fluid in order to make it capable of being punched, drilled, etc., like wrought-iron. The principal point in the operation is the temperature at which the iron is immersed in the fluid, the proper degree being the moment when the iron is reduced to a slight red heat, *i. e.*, as soon as the red heat is at the point of disappearing. The fluid in which the iron is immersed may be composed of various constituents, provided, however, that it contains no acids or other substances injurious to the iron. The best results are obtained with a solution of treacle and water of specific gravity 1.005. If the iron shows the proper degree of heat when taken from the chill it is directly brought into the fluid, otherwise

it is again heated somewhat above the required degree and, after cooling to a slight red heat, immersed in the fluid.

To make Steel so Soft that it can be Worked like Copper.—Pulverize beef bones, mix them with equal parts of loam and calves' hair and stir the mixture into a thick paste with water. Apply a coat of this to the steel and place it in a crucible, cover this with another, fasten the two together with wire and close the joint hermetically with clay. Then place the crucible in the fire and heat it slowly. When taken from the fire let it cool by placing it in ashes. On opening the crucible the steel will be found so soft that it can be engraved like copper.

New Way of Annealing Steel.—Heat the piece as slowly as possible, and when at a low red heat put it between two pieces of dry board and screw them up tight in a vise. The steel burns its way into the boards and, on coming together around it, they form a practically air-tight charcoal-bed. When it cools off the steel is apt to be found thoroughly annealed.

Two Ways of Annealing Steel.—It may be heated to a dull, red heat, covered with dry, warm sand and left to cool slowly; or heat and cover it up in the forge fire, and leave it there until the fire is out and all is cold. The other method is to heat the steel red hot; heat gradually, let it "soak," as the smiths say, until it is evenly heated, then remove it from the fire and take it to some dark place. Let the steel cool until you lose sight of the dull red in the dark; then cool off in cold water. A good "dark place" may be made by throwing your coat over a barrel, leaving just room enough to look in at the iron. This method is called "water anneal," and is based upon the theory that steel softens when cooled at a certain temperature.

Annealing of Bronze.—This process is especially employed in the preparation of alloys for cymbals, tam-tams, bells, etc. These alloys themselves are brittle, and the instruments cast from them become soft and sonorous only by immersing them while still hot, in cold water, then hammering and finally again heating and slowly cooling. While steel acquires hardness by quenching, a copper-tin alloy has the remarkable property of becoming sensibly softer and

more ductile when quickly cooled, and this property is made use of by heating the alloy to a dark red, or, in case of thin objects, to the melting point of lead, and then immersing in water. The alloy thus treated can be worked under the hammer and stretched without cracking or breaking.

To Harden Copper.—Among the latest methods resorted to for hardening copper is that of melting together and stirring until thoroughly incorporated, copper and from 1 to 6 per cent. of manganese oxide. The other ingredients for bronze and other alloys may then be added. The copper thus becomes homogeneous, harder and tougher.

To Case-harden Wrought-iron.—Wrought-iron is nearly pure decarbonized iron, and is not possessed of the property of hardening. But articles made of wrought-iron may be exteriorly converted into steel and afterwards hardened. The process is called case-hardening, and only differs from cementation in being carried on for a shorter time; it is seldom necessary to convert the iron into steel more than $\frac{1}{16}$-inch deep, unless where great stiffness as well as hardness is required. Case-hardened iron for various purposes is better than steel; it has the hardness and polish of steel externally, with a core of soft fibrous iron in the centre. Prussiate of potash renders iron nearly as hard as steel, by heating the iron to redness, sprinkling the potash finely powdered upon it, and then plunging the iron into pure cold water; but the hardness is confined to the surface, and only for articles not exposed to much wear can a sufficient coating of steel be obtained by this process. Greater and more uniform effect is produced by a perfectly tight box, and animal charcoal just sufficiently burnt to admit of being reduced to powder, in order that more of it may be got into the box with the articles; bones reduced to dust answer the purpose equally well. The box should be of plate-iron not less than $\frac{1}{8}$ to $\frac{1}{2}$-inch thick. The size and shape differ according to the articles operated upon. The box is furnished with an iron lid with two holes pierced in it for drawing testing pieces out, if required. The box may be strengthened against buckling by riveting a piece of iron about $\frac{3}{4}$-inch square inside the box about 1 inch from the

top; this will also answer for the lid to rest upon, and prevent it from pressing upon the articles when expanded by the heat. Clay or loam put between this iron square and the lid makes a secure joint. Two holes are pierced in the box at opposite sides just above the lid, for inserting 2 iron pins, and making the joint more secure. Upon a small scale a good box may be made by welding a plug into one end of a piece of wrought-iron pipe, and using a loose plug for the opposite end; the loose plug being fastened into place with an iron pin passing through it and the pipe, and luted with clay. For a small article a box may be formed of loam, which is gradually dried before it is exposed to a red heat. The articles being previously finished, except polishing, are put into the iron box in alternate layers with the animal charcoal, commencing on the bottom of the box with charcoal to the thickness of about ¾-inch; upon this a layer of the articles is placed, then another of charcoal about ⅓ of the first, and so on till the box is nearly full, finishing with charcoal about the thickness of the first layer, leaving room every way for the expansion of the articles by the heat, otherwise they will bend each other in the box. The packing completed the lid is put on and the box luted. The whole is now placed in a suitable furnace; the fire must not be urged, as the contents of the box require to be very gradually and uniformly heated to redness and retained at this heat for the period required for the depth of steel desired. In half an hour after the contents have arrived at the proper uniform temperature, the depth of steel will scarcely be the thickness of a dime; in an hour about double the depth, and so on. To tell when the central articles arrive at the proper heat, a testing piece is withdrawn; if it be not sufficiently heated, the heating must be continued a little longer; after a reasonable time another piece is withdrawn and if sufficiently hot, hardened in pure cold water; it can then be broken with the hammer, and the extent of the carbonization ascertained. Different kinds of iron absorb carbon unequally; consequently the testing pieces must be made of the same kind of iron as the articles. The more homogeneous the iron the more equally it absorbs carbon; consequently the less likely it will be to alter its shape in hardening. For test-

ing pieces, plain pieces of the same kind of iron as the articles may be used. They require to be brightened and are placed, at the time of the packing of the box, in the central part, in such a manner that they may be readily pulled out through the holes in the lid, either by a piece of iron wire attached, or by being made long enough to project through the holes, so that they may be gripped with pliers; the holes are luted the same as other parts. When the articles are sufficiently converted, the box is drawn from the fire, the lid taken off, and the contents are immersed in pure cold water; taken out when cold they are ready for polishing. To prevent rusting the articles may be dried by riddling in a sieve with dry sawdust, after which they are wiped with a greasy cloth. If the articles be immersed in oil instead of water, they will be much tougher but less hard, though sufficiently so for some purposes. It is not necessary to immerse them direct from the box, as it answers equally well to allow them to remain in the box until cool, and then reheat them in an open fire and immerse them separately. When the case-hardening is required to terminate at any particular part of an article, the part needed to be soft may be bound with thin iron wire and cased with loam. This prevents the iron from absorbing carbon at that part. The loam requires to be gradually dried upon the article previous to putting it into the box, otherwise it will crack. Another method is to shrink an iron ring or collar upon the part not required to be case-hardened; but this is not economical, especially when many articles require to be treated. To save the trouble of shrinking a collar on and getting it off again, a collar somewhat larger in diameter than the article may be used, the space between being filled up with loam. When a collar is shrunk upon an article it has generally to be cut asunder to be taken off, and is in future useless; it may be got off by hammering, but this will damage the article if it has been previously finished except polishing. If the article after being cemented with the carbon be immersed in water previous to taking off the collar, the latter will become hard because it has absorbed carbon; consequently it will require to be ground on the grind-stone before it can be cut off by the chisel, file or turning tool. In some in-

stances when case-hardening is to terminate at a particular part, it is more convenient and economical to postpone the finishing until after it has been cemented with carbon. Iron cemented with animal charcoal, however skillfully performed, is never so tenacious as iron cemented with wood charcoal; consequently it is unfit for cutting tools as it will not take a fine firm edge, and it is questionable whether it could be made suitable for the purpose by passing through the process of forging and melting.

To Case-harden Axle-arms.—Instead of using one large pan and plunging half a dozen arms into it, have for each arm a round, conical box, made of old boiler plate ⅜ inch thick, and about 2 or 3 inches longer and about 2½ inches larger in diameter inside than the arm. Into the box place sufficient animal charcoal to raise the collar of the axle-arm nearly flush with the top of the box, then surround the arm with the charcoal as far up as the collar, ramming it firmly down as you proceed, and finally cover the top of the charcoal with fire-clay, taking care to plaster the clay well round the axle and the edge of the box. The furnace is a small reverberating one, capable of holding 8 to 12 of these boxes at a time. The boxes are allowed to remain in the furnace 1 to 2 hours, according to the size of the axles, etc.

To Harden Cast-iron.—Mix 2 pounds of concentrated sulphuric acid and 2 ozs. of nitric acid with 2½ gallons of water. Plunge the article at a cherry-red heat into this mixture. The surface becomes very hard.

To Harden Cast-iron in a Simple Manner.—A cast-iron furnace, the size of which depends on that of the casting, is employed. It is provided front and back with doors, so that a small carriage can be run into it. The arrangement of the carriage depends on the form and size of the furnace, as well as on the objects to be hardened. A pipe perforated with small holes enters the furnace, and conveys into it heated steam. The objects to be hardened, especially cylinders, are allowed to rest as much as possible with their ends upon the carriage. For small objects, such as cutlery, a small furnace with a single door suffices. It must, however, always be provided with a carriage, in order to effect cooling off as quickly

as possible. The steam, with a tension of two atmospheres, is taken from an ordinary boiler. As near as possible to the furnace in which the hardening is effected is another furnace, through which the steam is conducted in a coil of pipe with a diameter of 15¾ inches, and the same height. Near the bottom of this coil is a cock for the discharge of condensed water. In the centre the coil is lined with brick-work; the fire in the furnace circulates around it and makes it red-hot, so that the steam passing through it to the hardening furnace, becomes superheated and suitable for hardening. For objects up to 0.59 inch thick, one hour suffices to complete the hardening.

To Quickly and Thoroughly Harden Soft Iron.—Moisten the object with water, and scatter powdered yellow prussiate of potash upon the surface. Then heat to a red heat, whereby the melting prussiate of potash coats the surface of the object; finally, quench quickly in cold water, and repeat the operation. A white heat must not be used, the iron not being hardened thereby but, on the contrary, oxidized. Red prussiate of potash must not be used, the hardening process not being successful with it.

To Harden Wrought-iron Parts of Machines.—The most suitable agents for this purpose are old leather, hoofs, horns, and bones; they are generally charred, coarsely powdered, and thoroughly mixed. A box of cast-iron or strong sheet-iron serves for the reception of the parts to be hardened. Upon the bottom of this box is first placed a layer of the cementing agent, about 1¼ inch deep. Upon this layer are placed the larger parts, in such a manner as not to touch each other. These parts are then covered 1¼ inch deep with the cementing powder, special care being had that all the separate parts are well covered. Upon this layer of cementing agent comes again a layer of iron parts, then again a layer of cementing agent, and so on until the box is full. The box is now covered with an iron lid, and the latter thoroughly luted with clay. The box is then placed upon the hearth, and surrounded and entirely covered with glowing coals, care being had to keep up a vigorous fire, so that the entire box may become red-hot at one time. Heating is continued for about two or three hours. In

the meanwhile a large tub full of fresh water is placed as near as possible to the hearth. In order to keep the water in the tub as cold as possible, it is advisable to arrange so that fresh water may run constantly into it. The fire is now removed from the lid, the box opened, and the separate articles taken out with tongs, and suddenly immersed in the water, where they remain until they are quite cooled off. The waving to and fro of the iron parts and a constant supply of fresh water cannot be too highly recommended, because all the labor, time, and expense would be lost if the articles be not sufficiently and energetically cooled off. In immersing the articles in the water care must be had not only to manipulate them rapidly, but they must also be introduced lengthwise, to prevent them as much as possible from becoming crooked. Immersing the articles flat would at once make them crooked. When taken from the water the articles are dried as quickly as possible upon hot stones, and then greased with oil.

To Harden Steel by Pressure.—This method of hardening steel, invented by Clemandat, of Paris, consists in heating the steel to a cherry red, and then subjecting it in a hydraulic press to a pressure of up to 2,000, 4,000, and 6,000 lbs. per 0.155 square inch. The steel is allowed to cool between the press-plates of the hydraulic press; it possesses the structure and qualities of steel obtained by tempering, and especially a very fine grain, great hardness and density. This phenomenon is explained by the simultaneous action of compression and cooling, the first replacing the hammering or rolling, and the latter the immersion in a cooling fluid.

To Harden Steel in Petroleum.—According to B. Morgóssy, the articles to be hardened are first heated in a charcoal fire, and, after thoroughly rubbing with ordinary washing soap, heated to a cherry red. In this condition they are quickly plunged into petroleum; ignition of the petroleum need not be feared, but, of course, an open flame must not be near at hand. Articles hardened according to this method show no cracks, do not warp in the least, and after hardening remain nearly white, so that they can be blued without previous rubbing with emery.

To Harden Steel so that the Exterior is Hard and the Interior

Soft.—Pulverize and mix yellow prussiate of potash 3 parts; borax, 1; saltpetre, 1; and sugar of lead, ⅓. Heat the steel to be hardened to a red heat, and scatter the powder over it. Then replace the steel in the fire, and when it has attained the proper degree of heat, cool it off in cold rain-water. Steel cooled off according to this method is very tenacious.

To Harden Small Drills.—The drill being filed the right size (the edge must not be hammered flat), it is moderately heated without becoming red, and then plunged into borax, whereby it becomes incrusted with borax and the air is excluded. The drill may now be hardened by heating to cherry-red, and finally plunged into a piece of borax, or, what is still better, into mercury, care being had not to inhale the vapor. The borax yielding to the heat of the drill, melts and cools off the drill. The results of various experiments of cooling off the drill incrusted with borax in water, oil, etc., were not so favorable as plunging it into borax or mercury. The drill becomes extraordinarily hard, without being brittle, so that articles which cannot be worked with drills hardened in the ordinary manner can be drilled with it. Watchmakers generally use broken broaches for such small drills, they being under the impression that they are of the best steel; such, however, is not always the case, the broaches having frequently been burnt in hardening; consequently the steel is spoilt for such purposes, and hence it is advisable to take new round steel wire.

Hardening-water for Steel.—Generally water at a temperature of from 50° to 77° F. is used for quenching the steel in hardening; the water should, however, not be too cold, as otherwise cracks or fissures are formed in the steel. Watchmakers and jewelers use hardening-water of 32° F., and frequently ice for very small articles. Water containing soap in solution is unsuitable for hardening.

Fluids for Hardening Steel Articles.—I. Rosin, 10 lbs.; train oil, 5 lbs.; lard, 2 lbs.; and assafœtida, 4½ ozs. By using, this bath steel, even if frequently heated, retains its former characteristics.

II. *Especially Used for Hardening Cutlery.*—Refined borax,

2 lbs.; sal-ammoniac, 4 lbs.; water, 3 quarts; and French red wine, 4 ozs.

III. Sal-ammoniac, 3 lbs.; potash, 1 lb.; water, 4 gallons; red wine or vinegar, 1½ pints; and tartaric acid, 1 lb.

Hardening Compound for Steel.—Pulverize 3 parts by weight of prussiate of potash, 1 of borax, 1 of saltpetre, and ½ of sugar of lead, and intimately mix the whole. After heating the steel to be hardened to a red heat, take it from the fire and scatter the powder over it. The steel is then replaced in the fire, and after having been brought to the required degree of heat, cooled in cold rain-water.

Hardening Mixture, Patented by J. Robb, of Dundee, Forfarshire.—The red-hot iron is plunged into a mixture of yellow prussiate of potash, 1 lb.; rock salt, 2 lbs.; bone-dust, 2½ lbs.; charcoal, 2 ozs.; and hydrochloric acid, ½ pint. The metal is then again heated, once more plunged into the mixture for a few minutes, and then, while still hot, immersed in cold water. The proportions of the above substances may vary, and, in some cases, lime may be added.

To Avoid Cracks, Curving, and Warping in Hardening Steel.—The following directions should be observed: 1. Thin flat pieces should be immersed, edge foremost, with uniform velocity. If allowed to touch the water with the broad surface they would warp. 2. Articles considerably thicker on one side than on the other, for instance, razors, must be immersed with the thick side foremost, as otherwise the thin side would show cracks. 3. The article is to be immersed in the hardening-water as far as it has been made red hot; otherwise, a crack is formed on the place of immersion. 4. In hardening cast-iron articles tipped with steel, it must be taken into consideration that cast-iron contracts more strongly than steel, and that consequently the article would every time curve. To avoid this, curve the article before hardening to the opposite side.

How to Harden Thin Steel Plates.—Provide two pieces of iron about 6″ x 6″ x 1″, with one surface on each block planed, spread a liberal supply of good sperm oil on each planed surface, place the blocks near by in level position to insure an even thickness of oil,

and keep the blocks cool. Immerse the steel plates in molten lead, as far as they are required to be hardened; when a red heat is obtained, drop the piece quickly upon the oiled surface of one of the iron blocks, and simultaneously lay the other iron block upon the work; when cool, they will be found true. This system has been successfully used for years for hardening thin steel tools.

Another method is as follows: Sheet steel $\frac{1}{16}$ inch thick can be successfully hardened between two cast-iron blocks placed in a screw-press or any kind of hand-press. Holes should be drilled in the corners of the lower block for spiral springs of sufficient power to keep the blocks apart.

The steel should be heated (a small gas furnace is preferable), and quickly inserted between the blocks, and pressed hard until cool enough to insure against drawing temper. A good plan is to have two pieces in the furnace at once, and allow one to cool while the other is heating.

To draw the temper, brighten part of the piece on an emery-wheel, and then run them together with sand in a sheet-iron tumbler, under which is a fire (a few gas-jets are the best), until the desired color is obtained.

Hardening of Steel According to Newton and Ames.—According to the patent considerable hardness can be imparted to the surface of steel objects by mechanical means. The process consists in gently pressing a slowly revolving steel object against a quickly revolving emery wheel. Besides its revolution the object to be hardened has a horizontal motion in a lateral direction, so that with each revolution it is pushed sideways nearly 0.78 inch. The hardening process is finished when the object is out of reach of the emery wheel. The hardened layer is about 0.03 millimetre thick, and is capable of resisting the best tools hardened in the ordinary manner.

To Harden Steel in Sealing-wax.—Watch and clock-makers and engravers harden their steel in sealing-wax. The article is heated to a white-heat and thrust into sealing-wax, allowed to remain for a second, then withdrawn, and again inserted in another part of the wax. This treatment is continued till the steel is cold and will no

longer enter the sealing-wax. The extreme hardness of steel thus prepared enables one to engrave or drill steel hardened by other processes, the drilling or engraving tool being first dipped in oil of turpentine.

To Harden Springs and Saws.—Springs and saws are generally hardened in various compositions of oil, suet, wax and other ingredients, which, however, lose their hardening property after a few weeks' constant use. The saws are heated in long furnaces and then immersed horizontally and edgeways in a trough containing the composition; two troughs are commonly used, the one until it gets too warm, then the other for a period, and so on alternately. Part of the composition is wiped off the saws with a piece of leather, when they are removed from the trough, and they are then heated one by one over a clear, coke-fire until the grease ignites; this operation is called "*blazing off.*"

The composition used by an experienced saw-maker is 2 lbs. of suet and ¼ lb. of beeswax to every gallon of whale oil; these are boiled together, and will serve for thin works and most kinds of steel. The addition of black resin to the extent of about 1 lb. to the gallon makes it serve for thicker pieces and for those which did not become hard by the first application; but the resin should be added with judgment or the objects will become too hard and brittle. The composition is useless when it has been constantly employed for about a month; the period depends, however, on the extent to which it is used. The trough should be thoroughly cleaned out before a new mixture is placed in it.

The following composition is recommended: Spermaceti oil, 20 gallons; beef suet, rendered, 20 lbs.; neat's-foot oil, 1 gallon; pitch, 1 lb.; black resin, 3 lbs. The last two articles must be previously melted together, and then added to the other ingredients. The whole is then heated in a suitable iron vessel with a close cover until the moisture is entirely evaporated, and the composition will take fire on a flaming body being presented to its surface. The flame must be instantly extinguished by putting on the cover of the vessel.

When the saws are needed to be rather hard, but little of the

grease is burnt off; when milder, a larger portion; and for a spring temper, the whole is allowed to burn away. When the work is thick or irregularly thick and thin, as in some springs, a second and third dose are burnt off to insure at all parts equality of temper.

Gun-lock springs are sometimes literally fried in oil for a considerable time over a fire in an iron tray; the thick parts are then sure to be sufficiently reduced, and the thin parts do not become the more softened from the continuance of the blazing heat.

Springs and saws appear to lose their elasticity after hardening and tempering from the reduction and friction they undergo in grinding and polishing. Towards the conclusion of the manufacture the elasticity of the saw is restored principally by hammering and partially by heating over a clear, coke-fire to a straw-color. The tint is removed by very dilute hydrochloric acid, after which the saws are well washed in clear water and dried.

Watch springs are hammered out of round steel wire of suitable diameter until they fill the gauge for width, which at the same time insures equality of thickness; the holes are punched in their extremities, and they are trimmed on the edge with a smooth file. The springs are then tied up with binding wire, in a loose open coil, and heated over a charcoal fire upon a perforated revolving plate; they are hardened in oil and blazed off.

The spring is now distended in a long metal frame similar to that used for a saw blade, and ground and polished with emery and oil between lead blocks. By this time its elasticity appears quite lost, and it may be bent in any direction; its elasticity is, however, entirely restored by a subsequent hammering on a very bright anvil.

The coloring is done over a flat plate of iron or hood, under which a small spirit-lamp is kept burning. The spring is continually drawn backwards and forwards about 2 or 3 inches at a time, until it assumes the orange or deep blue tint throughout, according to the taste of the purchaser. By many the coloring is considered to be a matter of ornament and not essential. The last process is to coil the spring into the spiral form that it may

enter the barrel in which it is to be contained. This is done by a tool with a small axis and winch-handle and does not require heat.

The balance springs of marine chronometers are wound into the square thread of a screw of the appropriate diameter and coarseness. The two ends of the spring are retained by side screws, and the whole is carefully enveloped in platinum foil and tightly bound with wire. The mass is next heated in a piece of gun-barrel closed at the one end and plunged into oil, which hardens the spring almost without discoloring it, owing to the exclusion of the air by the close platinum covering which is now removed, and the spring is let down to the blue before removal from the screwed block.

The balance or hair springs of the best watches are hardened in the coil upon a plain cylinder and are then curled into the spiral form between the edge of a blunt knife and the thumb, the same as in curling up a narrow ribbon of paper or the filaments of an ostrich feather.

In hardening bow-springs for all kinds of vehicles they are heated by being drawn backwards and forwards through an ordinary forge fire, built hollow, and then they are immersed in a trough of plain water. In tempering them they are heated until the black red is just visible at night; by daylight the heat is denoted by its making a piece of wood sparkle when rubbed on the spring, which is then allowed to cool in the air.

To Harden Files and Other Steel Instruments.—The files, etc., are first coated with a paste prepared by boiling glue and salt in yeast and thickened by an addition of wood charcoal and graphite (black lead). Upon this coat is scattered a coarse powder consisting of a mixture of horn, wood charcoal and common salt. A solid crust is formed upon the files, which protects them from a displacement of the cuts by the metal and conveys to them oxygen while being heated. For tempering the files are brought into a lead-bath. To prevent the oxidation of the lead on the surface a mixture of potash, soda and tartar is scattered upon it. The files remain in the bath 5 to 8 minutes, according to their thickness, and are then immersed in water.

To Harden Steel Instruments.—The instrument is first brought to

a cherry heat, if possible in a charcoal fire. The edge is then quickly dipped in a mixture of black soap and finely pulverized yellow prussiate of potash, taken out and quenched, but only half of it, in clear water, in which it remains until cold. Only in this manner can the warping of the object be prevented and the edge thoroughly hardened, while the remaining portion which may have to serve for securing the instrument in a handle remains sufficiently soft to allow of holes being drilled in it.

To Harden Tools.—The following process has the advantage of enabling one to give to castings any desired degree of hardness without their warping or becoming too hard and brittle in the inside. For the hardening agent take Peruvian bark, 500 parts by weight ; hartshorn shavings, 50 ; common salt, 25 ; yellow prussiate of potash, 15 ; saltpetre, 15 ; and black soap, 100. Spread out the soap in a layer about 0.39 inch deep, and after scattering upon it the pulverized mixture of the other five ingredients thoroughly knead the paste thus formed. This kneading should, however, not be continued longer than is absolutely necessary to form the mass into a stick of about 2 inches diameter. After about 24 hours' drying the mass is ready for use. In superficial hardening of punches, twisted augers, etc., care must be had to heat the cast-steel article only dark red, *i. e.*, only to such an extent that on cooling in cold water its hardness is not increased. Then coat the portions to be hardened with the hardening agent and cool off the object. The interior as well as all portions not coated remains perfectly soft and tough, while the prepared portions become as hard as glass. To accurately hit the correct degree of heating the cast-steel it is recommended to make in the above manner several experiments with a round steel wire about ½ inch thick. By testing the fracture with a file the condition of the interior is then ascertained.

Hardening Gun-barrels According to Neunert.—The barrel to be hardened is placed in a gas-pipe of suitable size, the lower end of which is made narrow to prevent the barrel from slipping out while in a vertical position. Several such pipes containing gun-barrels are then heated to a red heat in a reverberatory furnace, when some hardening compound is thrown into every barrel. The pipes are

now taken from the furnace, placed in a vertical position under a hose and hardening water is passed through each barrel under a pressure of ½ to ¾ atmosphere. It is very advantageous to add a small quantity of sulphuric and nitric acids to the hardening water.

To Harden the Bores of Musket-barrels.—The barrels are secured in a frame so that they can be turned during heating to prevent warping. Through the barrels heated to a red heat is then conducted a jet of a solution of potassium ferrocyanide, whereby the bore acquires considerable hardness in consequence of saturation with carbon and nitrogen, while the chemical constitution of the rest of the metal is unchanged.

The same object is attained by a less costly method, as follows: The barrel is filled with nitrogenous (animal) waste, such as leather, hair, horns, hoofs, etc., suitably comminuted, or with a mixture of yellow prussiate of potash, borax and corn meal, or yellow prussiate of potash and charcoal. Both ends of the bore are then closed by a cork or clay and the barrel is heated as uniformly as possible.

Adam Schaefer's Fluid for Hardening Steel, which serves to improve the quality of many varieties of steel, consists principally of ordinary resins, linseed oil, glycerin and powdered wood charcoal, the ingredients being intimately mixed and the mixture heated. The steel at a bright cherry-red heat is dipped in the fluid and, after cooling in it, again heated and subjected to one of the usual methods of hardening by water, oil or melted compositions of metal. The effect produced by this process is said especially to show itself in burnt cast-steel, which thereby regains its original qualities, while softer varieties of steel acquire the advantages of cast-steel. Tools made from Bessemer steel, which cannot be hardened in the usual manner, may, after passing through the above-described process, be used for cutting castings which frequently resist the best tools made of tungsten steel.

To Harden Copper.—To impart to copper and copper alloys greater hardness and tenacity the following process is recommended: Melt the copper with 1 to 6 per cent. of oxide of manganese (the naturally occurring black oxide will do) in a crucible, stir thor-

oughly and after carefully removing the scum formed pour it out. The same process is followed in the preparation of brass, the necessary quantity of zinc being added to the melted copper and oxide of manganese. Though chiefly used for brass alloys, the process is suitable for all alloys of which copper forms the principal constituent.

To Harden Zinc.—According to Brignol, Fargon and Delpierre's method from 1.76 to 3.52 ozs. of sal-ammoniac per pound, according to the hardness desired, are brought into the melted metal. Zinc thus treated, it is said, can be worked with the turning-tool and file, and can in many cases be advantageously substituted for bronze.

Hardening Compound.—Pulverize and mix intimately 1 part each of pulverized yellow prussiate of potash, purified saltpetre and calcined cows' hoofs, $\frac{1}{30}$ of gum arabic, $\frac{1}{30}$ of aloes and ½ of common salt. Scatter the compound upon the steel while at a red heat, and upon the wrought-iron while at a white heat, and burn it thoroughly in.

New Case-hardening Compound.—This compound is very efficacious for case-hardening iron. It consists of lampblack, 16 parts; sal-soda, 18; muriate of soda, 4; and black oxide of manganese, 1.

Agents for Hardening, Improving and Welding Steel.—The so-called "*Steel-powder No.* 1," prepared by A. Schenker's Wittwe at Rheinfelden, is claimed to possess the property of improving steel; it may also serve as welding powder and to restore burnt steel to its original condition and hardness. This powder consists of ⅓ borax, ⅓ ammonium chloride and ⅓ organic substance (resin, white pitch) with a trace of silicic acid. By the addition of this powder during forging, turning tools, etc., are much improved.

Powder No. 2, for Welding Cast-steel with the Assistance of Heat, consists of ferric oxide, 25 per cent.; ammonium chloride, 15 per cent.; silicic acid, 50 per cent.; and carbonate of lime, 10 per cent.

Powder No. 3, for Hardening Steel, is claimed to restore to "fatigued" steel its original strength. It consists of 48 per cent. nitre, 58 per cent. organic substance (very likely pulverized hoofs) and about 2 per cent. silicic acid.

Powder No. 4, the so-called "Iron Powder," is used for superficially hardening wrought and ingot iron. It is claimed that by scattering it three times upon the articles and burning off, as great a depth of steel is obtained as by case-hardening for six hours. It consists of 15 per cent. sodium chloride, 25 per cent. pyrolusite, 10 per cent. sodium carbonate and 50 per cent. organic substance. Color, reddish-brown. This powder is also suitable for case-hardening.

The following agents are brought into commerce by Karl Küpfer, Biel, Switzerland: Hardening mass A is a brown-red mass drawing threads; it consists very likely of train oil, 50 parts; ordinary colophony, 40; and turpentine resin, 10. It is used for hardening as well as for restoring burnt steel. The tools or other articles to be hardened are brought to a red heat in a charcoal fire and plunged into the mass until black. They are then returned without previous cleaning to the fire and when at a red heat hardened in the *hardening-water B*. This is prepared by boiling pure well-water in an uncovered vessel, pouring it off when cold from the sediment and adding for each quart of water 14 drachms of a mixture consisting, according to analysis, of 40 per cent. nitre, 59 per cent. ammonium chloride and a trace of sodium sulphate (the latter perhaps only as an impurity).

The *"Steel-hardening Powder C"* consists of 5 five per cent. nitrate of soda, 15 per cent. ammonium chloride, 25 per cent. yellow prussiate of potash and 55 per cent. organic substance (pulverized hoofs).

The *"Hardening-water D"* consists of a concentrated solution of salts, the same as *B*, 4 lbs. of powder being taken to every 10 quarts of water and when dissolved 1 lb. of pure sulphuric acid added.

Tempering Colors of Steel.—By superficial oxidation tempering colors are formed in hardening steel, which serve as a guide as regards the temperature and degree of hardness.

Temperature.	Color.	The steel is suitable for
428 ° F.....	Pale yellow.	Surgical instruments.
449.6 "	Light straw-yellow.	Surgical instruments.
469.4 "	Straw-yellow.	Razors and pen-knives.
491.0 "	Brown-yellow.	Scissors, chisels.
509.0 "	Brown with purple stains	Axes, planes, irons, bread-knives.
530.6 "	Purple	Table-knives,
550.4 "	Pale blue.	Sword-blades, watch-springs.
559.4 "	Corn-flower-blue.	Fine saws, drills, fencing-foils.
600.8 "	Dark blue.	Hand-saws.

For Baths Used by Cutlers and Others in Tempering and Heating Steel Articles, Parkes and Martin propose the following alloys:

No.	Use.	Composition.		Melting points. Degrees F.
		Lead. Parts.	Tin Parts.	
1	Lancets.....	7	4	420
2	Other surgical instruments.....	7½	4	430
3	Razors	8	4	442
4	Pen-knives.....	8½	4	450
5	Knives, scalpels, etc.....	10	4	470
6	Chisels, garden-knives.....	14	4	490
7	Hatchets.....	19	4	509
8	Table-knives.....	30	4	530
9	Swords, watch-springs.....	48	4	550
10	Large springs, small saws.....	50	4	558
11	Hand-saws.....	Oil, boiling.		600
12	Articles of low temper.....	1	4	612

Effect of Temperature on Steel.—At 570° F. a dark blue color is produced upon polished steel, which is changed to a pale blue at 590° F. Oil or grease of any kind will answer for drawing the temper of cutlery. The temper for lancets is obtained at 430° F., axes at 500° F., swords and watch-springs at 530° F., small saws at 570° F. and large saws at 590° F. Copper-colored spots are not produced by tempering, but they may be obtained on the polished

surface of steel by immersing the article in a solution of sulphate of copper.

To Temper Steel by Electricity.—Among the more recent uses to which electricity has been applied is that for tempering watch-springs and other forms of spring steel, whether in the form of ribbon or wire. The steel is wound on a spool, whence it passes down through a bath of oil. An electric current is sent through the wire of such strength as to keep it at the proper redness to answer the desired requirements of temper. As the heating is not done in contact with the air, but is entirely beneath the surface of the oil, there is no trouble from blistering, as in the ordinary methods. The final temper is drawn in the same manner, and the wire or ribbon is finished by means of rolls. The process is also applied to a number of springs beside those for watches, including piano wires. In all cases the process can be controlled to a nicety, both as to exact temper and its uniformity through the wire.

To Temper Mining-picks.—When ready for hardening, the pick should be heated in the blaze of a charcoal fire until red hot and then plunged into cold rain water and kept there until it is nearly cold. Some blacksmiths use salt-water. No salts of any kind should exist in the water, but the water should be cold. If it is warm throw in a little ice and the tempering will be all the better. Pure soft water for hardening will make a tougher pick and one less liable to crack at the edges than where salt-water is used. The last hammering of a pick should always be given on the flat sides, across close to the edges, and then up each side about an inch. By doing so the corners will be less liable to crack.

To Temper Taps and Dies.—The great difficulty in hardening tools is principally their liability to twist or get out of truth; secondly, cracking (especially if large) after hardening; thirdly, getting the right temper. First, carefully select your steel; let it be of the best cast, with a medium grain; a fine-grained steel will break when much less force is applied than a coarser-grained, and although it will take a keener edge it will not resist the strain required by a tap or rimer. Next centre it and turn off the scale and soften. The object of softening after the scale is removed is

to make the grain of the steel equal throughout; if it be softened with the scale on it will generally cast. To soften enclose the articles in a piece of gas-tube, filling up with wrought-iron turnings and plugging the ends with clay, making the whole red hot and allowing it to cool very slowly, *i. e.*, leaving it in hot ashes all night. This method makes the steel very soft and equalizes the grain. After softening turn up the work, taking care not to bend or straighten it, should it have cast, as it probably will in the process of softening. The reason for this is that if the steel be bent or hammered the grain will be closer in one place than in another, and heat has a great tendency to bring it back to its original position. The next thing after finishing your tool is to harden it: first, slightly heat it over a gas or other flame and rub it all over with a mixture of castile soap and lampblack. This is to prevent the edges from being burnt. The next is to get a thick iron pipe 2 inches in diameter and ¾-inch bore. This is well filled up with taps or dies and charcoal-dust, the ends being closed with clay as before; this is placed in the furnace and occasionally turned until it is one uniform heat of cherry-red or on the outside a trifle hotter. It is then carefully removed from the fire, one end of the clay is knocked off, and the contents are allowed to drop perpendicularly into a solution of water, chloride of sodium and nitrate of iron; this solution is kept at a temperature of 60° F. The articles to be hardened should remain at least ¼ hour before being removed. This method of hardening may be summed up thus: make the steel of one grain throughout, prevent it from oxidizing whilst being heated, allow every part to heat at the same time, avoid bending while hot, and, lastly, restore if possible by replacing the loss of carbon caused by heating.

Improvements in Tempering and Hardening Steel and Iron.—Glycerin is used in tempering steel, cast-steel or cast-iron. The specific gravity of the glycerin may be varied between 1.08 and 1.26 at 59° F. by adding water according to the composition of the steel. The quantity of glycerin should be from 1 to 6 times greater in weight than the weight of the pieces to be plunged into it, and its temperature may be varied from 59° to 392° F., according to the

hardness of the metal. The harder the steel to be tempered the higher the temperature should be, and for a mild steel a low temperature should be used. To increase the quenching power of the bath various salts may be added to the glycerin solution. Thus, when a hard temper is wanted, protosulphate of manganese may be added in quantity varying from 1 to 34 per cent. of the liquid or from ¼ to 4 per cent. of potassium sulphate. For a softer temper 1 to 10 per cent. of manganese and 1 to 4 per cent. of potassium chloride may be added. The principal advantages to be derived from these methods are: 1. The temperature of the aqueous solutions of glycerin may be varied within wide limits, the boiling point of pure glycerin being 84.2° F. 2. Owing to the fact that solutions of glycerin in water dissolve most salts that are soluble in water, the quenching properties of the bath may readily be varied by dissolving such salts in it as will suit the kind of metal to be tempered and the degree of temper required.

To Temper Brass.—Brass not hardened by mixture, but by compression, either by rolling, hammering, wire drawing or any other process which compresses the particles of metal, can be tempered just as easily and in the same manner as an equal-sized piece of hardened steel would be tempered, *viz.*, by heat. By placing a small piece of polished steel on the brass object to be tempered and applying the heat so as to affect equally the brass and steel, the color of the steel will indicate the temper in exact proportion to every shade of color of the steel.

To Temper Magnets.—A combined process for tempering and magnetizing steel bars for magnets is employed by M. Ducoetet. He uses a water-tight vessel, at the bottom of which are two soft iron pole pieces; the poles of a powerful electro-magnet are placed underneath these. The vessel is partly filled with water, and a layer of oil is above this. The red-hot bar is passed through these. Its passage first through the oil is found to soften the steel without depriving it of its power of being magnetized.

VI.

BRONZING AND COLORING.

Metals are bronzed by one of two methods, the color being produced either by chemical agents or by the application of bronze powders. For the latter purpose there are found in trade bronze powders made of brass in an impalpable state of division and which present the most varied shades, according to the degree of oxidation which the brass undergoes when heated in contact with the air. These bronze powders are applied upon metals to imitate bronze. The operation is entirely mechanical. After the object has been more or less cleaned, it receives a thin coating of a fatty drying varnish which is allowed to become nearly dry. A good varnish for the purpose is made as follows: Boil 1 to 2 lbs. of linseed oil in an earthen vessel for 2 hours; then remove it from the fire and when somewhat cooled off add gradually 1.23 ozs. of red lead. If on adding the red lead a red scum is formed upon the surface of the oil, the oil is too hot and the addition of red lead has to be interrupted until the oil is cooler. The addition of red lead is succeeded by that of a like quantity of white litharge. The varnish is then allowed to stand in the sun for a few days to clarify and finally kept for use in a glass or tin vessel. To give the object a *gold bronze*, ochre is triturated with the varnish and some blue or black mixed with it, so that a dirty green color results. Apply two or three layers of this color to the surface of the object by means of a soft brush, allowing the first layer to dry before applying the next. The last coating, however, must not be allowed to become entirely dry. The bronze powder is laid upon this layer with a badger brush or otherwise, and adheres strongly. After drying and dusting off the superfluous bronze powder with a stiff brush the whole is covered with a coat of transparent and colorless varnish. This process evidently fills up the details and is suited only to large pieces which are imperfectly finished.

If the article is to receive a *silver bronze*, rub some zinc white and lampblack into the above-mentioned varnish so that a sort of

silver-gray color is obtained. Apply 2 or 3 coats of this paint to the article and bronze with silver bronze before the last coat is entirely dry. Very beautiful effects can in this manner be obtained by the use of various ground-colors, such as colcothar, leaf-green, dark gray and even black. In bronzing iron it is very advantageous to first coat it, without regard to the succeeding colors, with red oxide of iron, rubbed up in varnish, and then apply the actual colors. A very neat bronzing is produced with a paint of graphite and varnish, the last coat of which is dusted over before becoming entirely dry with aluminium bronze powder, the whole acquiring thereby the appearance of polished iron.

Copper Bronze upon iron and zinc is obtained by coating the metal with a brown lacquer or varnish and dusting copper-dust upon it in the manner previously described. Copper-dust may also be mixed with spirit lacquer and applied together with the lacquer.

Red Bronze is produced by the application of red bronze lacquer or red bronze powder or red mosaic gold. For bronzing with red bronze lacquer the objects must be clean and bright, since every stain shows through the lacquer. For bronzing with red metallic bronze the object is first coated with varnish and the bronze powder laid upon it with a velvet rag or soft brush.

Green Bronze upon tin, zinc and lead may be produced by the application of green bronze lacquer of a dull lustre or of green varnish. The green for the bronze color is best prepared by mixing Frankfort black with chrome yellow.

As regards bronzing by chemical agents it is not necessary to give a detailed description of the mode of application, since a large number of receipts and their use for bronzing metals and alloys are given as follows:

French Bronze.—A new bronze upon French bronze figures shows all shades of pale or clay-yellow to red-brown, and of red to dark and black-brown. It has a bronze-like appearance, and adheres tightly to the metal, *i. e.*, is chemically combined with it. To produce such colorations, solutions of sulphur combinations of arsenic and antimony have been successfully used. After cleaning

and pickling, the articles must be subjected to a thorough washing with water, as otherwise every trace of acid left behind will later on in drying or bronzing penetrate through the seams and produce indelible stripes and stains. Great care must also be had in drying the article. For applying the solutions a tuft of cotton, or a soft, close brush, is used. The operation is best commenced by first applying a dilute solution of ammonium bisulphide as sparingly as possible, brushing over a certain limited portion of the figure at one time. The quicker and more uniformly this is done, the better and more beautiful the bronzing will be. After drying the sulphur separated out is brushed off, and a solution of sulphide of arsenic in ammonia applied, the result being a coloration similar to mosaic gold. The oftener this solution of sulphide of arsenic is applied the browner the color becomes, and a very dark brown can be finally obtained by a solution of sulphide of arsenic in ammonium bisulphide. By solutions of sulphide of antimony in ammonia or ammonium sulphide the coloration becomes reddish, it being possible to produce the most delicate rose color as well as the deepest dark red. By rubbing some places more vigorously, a very fine metallic lustre is produced. Ammonia or ammonium sulphide redissolves the bronzing, so that places not thoroughly colored can be improved, though in such case it is better to rub off the entire figure with ammonium sulphide. In the same manner as the solutions in ammonia or ammonium sulphide, those in hydrate or sulphide of potassium or sodium can also be used, the latter being in some cases even more advantageous. By slightly pickling the object the color of the bronze is changed. If a casting of bronze or brass is left too long in the pickle, the metal becomes coated with a greenish-gray film, which, on rubbing with a piece of cloth, becomes lustrous and adheres firmly. On treating with the above-mentioned metallic sulphides this coating acquires a dull yellow coloration. The number of such agents for bronzing can, undoubtedly, be still further augmented, and an operator having some knowledge of chemistry may be able to use many other similar solutions of metallic salts. Heat must not be used.

Blue Bronze.—Prepare a sand-bath as large as the article to be

bronzed. Cleanse the article from all grease by dipping in boiling potash lye, and then treat it with white vinegar. Wipe and dry the surface thoroughly, and rub it with a linen rag moistened with hydrochloric acid. Allow the coating to dry for a quarter of an hour, and then heat the article on the sand-bath until it has acquired the desired color, when it should be removed.

Brown Bronze.—Observe the same directions as in the foregoing. The blue bronze is finally rubbed over with a linen rag saturated with olive oil, which will change the blue color into brown.

Bronzing by Dipping in Melted Bronze.—This process is similar to tinning, galvanizing, etc. The bright metal is dipped in bronze melted under a cover of borax in an iron crucible, and moved in it until it has acquired the temperature of the melted alloy and becomes uniformly coated with it. The bronzed article is then taken out, and allowed to cool upon a grate by moving it until the coating congeals. Large pieces are to be sufficiently heated before dipping, in order to prevent the melted bronze from being cooled off too much.

Bronze Liquid.—Dissolve sal-ammoniac, 1 oz.; alum, ½ oz.; arsenic, ¼ oz., in strong vinegar, 1 pint. The compound is immediately fit for use, and, where the metal is good, is seldom found to fail.

Cheap Bronze.—Make into a paste with oil, and melt together verdigris, 16 ozs.; flowers of zinc, 8 ozs; borax and saltpetre, of each 4 ozs.; corrosive sublimate, 2 drachms. This bronze is used in the commoner kinds of tea-boards, etc.

To Bronze Small Brass Articles.—Oxide of iron, 3 parts; white arsenic, 3 parts; hydrochloric acid, 36 parts. Clean the brass well to get rid of grease, etc., and apply with a brush until the desired color is obtained. Stop the process by oiling well, when the article may be varnished or lacquered.

Bronzing Process Used in the Paris Mint.—Powder and mix 1 lb. each of verdigris and sal-ammoniac. Take a quantity of this mixture as large as a hen's egg, and mix into a dough with vinegar. Place this in a copper pan (not tinned), boil in about 5 pints of water for 20 minutes, and then pour off the water.

For bronzing, pour part of this fluid into a copper pan; place the medals separately in it upon pieces of wood or glass, so that they do not touch each other, or come in contact with the copper pan, and then boil them in the liquid for a quarter of an hour.

To Bronze Copper.—Dissolve 30 parts of carbonate or hydrochlorate of ammonium and 10 parts each of common salt, cream of tartar, and acetate of copper in 100 parts of acetic acid of moderate concentration, or in 200 parts of strong vinegar, and add a little water. When an intimate mixture has been obtained, smear the copper object with it, and let it dry at the ordinary temperature for 24 to 48 hours. At the end of that time the object will be found to be entirely covered with verdigris presenting various tints. Then brush the whole, and especially the reliefs, with a waxed brush, and, if necessary, set off the high reliefs with hematite or chrome yellow, or other suitable colors. Light touches of ammonia give a blue color to the green portions, and carbonate of ammonium deepens the color of the parts on which it is laid.

To Bronze Copper Bluish-gray.—According to Dr. Böttger, a brightly polished sheet of copper acquires a beautiful bluish-gray color by applying to the surface a fluid obtained by the warm digestion of cinnabar with a solution of sodium sulphide, to which some caustic lime has been added.

Green Bronze for Brass.—I. Mix strong vinegar, 80 parts; mineral green, 1; red umber, 1; sal-ammoniac, 1; gum arabic, 1; ferrous sulphate (green vitriol), 1, and add 4 parts of Avignon berries (fruits of *Rhamnus infectorius*). The articles to be bronzed should be cleansed with dilute nitric acid, then rinsed in water and the fluid applied with a brush. Should the color not be dark enough heat the article until it cannot be held in the hand and then give it a coat of spirit of wine mixed with a little lampblack. Finally apply a coat of spirit varnish.

II. Add to a solution of 8½ drachms of copper in 1 oz. of strong nitric acid, 10½ ozs. of vinegar, 3½ drachms of sal-ammoniac and 6¾ drachms of aqua ammonia. Put the liquid in a loosely-corked bottle and allow it to stand in a warm place for a few days, when it may be used. After applying it to the objects, dry

them by exposure to heat, and, when dry, apply a coat of linseed oil varnish, which is also dried by heat.

To Bronze Articles of Copper and Brass.—Neutralize 20 parts by weight of ammonia with vinegar and compound the solution with 10 parts of verdigris and 6 of sal-ammoniac. Larger articles after being freed from grease and other impurities are brushed with the solution, the operation being repeated until the desired shade of color is produced. The articles are dried at the ordinary temperature of a room. Smaller articles are dipped, with constant stirring, in the fluid heated nearly to the boiling point. The desired coloration having been attained, the solution is poured off and replaced by hot water, the rinsing being twice repeated with stirring. The articles are best dried in saw-dust.

Brown Fire-proof Bronze upon Copper and Brass.—Dissolve 1.12 drachms each of pulverized verdigris and finely powdered sal-ammoniac in 1 pint of water, let the solution stand covered 3 or 4 hours and then add 1½ pints of water. In bronzing hold the copper article, which should be perfectly clean, over a coal fire and heat to a uniform heat and color. Then apply the solution and dry carefully. Tinned copper must not be heated enough to melt the tin. By thus treating copper 5 or 6 times it acquires a brassy color, and after 6 to 10 applications a beautiful yellow tint. If it is desired to give a copper article a color shading from yellow into brown it must not be hot when the mixture is applied; for light brown the operation is to be repeated 20 to 25 times. When the desired color has been obtained place the article at once in clean water, but do not polish or dry it immediately after taking it out. In fact, the greatest care is here required. It is best to dry the article over a moderate coal fire, when the bronze will become durable and fire-proof.

Green Bronzing.—The repeated alternate applications to copper or brass of dilute acetic acid and exposure to the action of the fumes of ammonia will give a very antique-looking green bronze; but a quick method of producing a similar appearance is often desirable. To this end the articles may be immersed in a solution of 1 part of perchloride of iron in 2 parts of water. The shade becomes

darker with the length of immersion. *Or*, the articles may be boiled in a strong solution of nitrate of copper. *Or*, they may be immersed in a solution of 2 ozs. of nitrate of iron and 2 ozs. of hyposulphite of sodium in 1 pint of water. Washing, drying and burnishing complete the process.

Bronzing of Cast-iron.—To give cast-iron the appearance of bronze coat the polished iron with a thin layer of linseed oil or linseed oil varnish and thoroughly heat it in the air to bring about the oxidation of the metal. The temperature must be higher or lower according to whether a pale yellow or dark brown coloration is to be produced. The so-called *Tucker bronze* is obtained by greasing the polished iron and exposing it for 2 to 5 minutes to the action of vapors produced by a bath composed of equal parts of concentrated nitric and hydrochloric acids, then coating the iron with vaseline and heating until the latter commences to decompose.

Gold Bronze of Great Lustre on Iron.—Dissolve 3 ozs. of finely powdered shellac in 1¾ pints of spirit of wine. Filter the varnish through linen and triturate a sufficient quantity of Dutch gold with the filtrate to give to it a lustrous appearance. The iron, previously polished and heated, is brushed over with vinegar and the color applied with a brush. When dry the article may be coated with copal lacquer to which some amber lacquer has been added.

To Bronze Cast-iron.—First clean and smooth the surface and then coat it uniformly with a layer of vegetable oil, for instance a poor quality of olive oil. Then heat, without, however, raising the temperature to the burning point of the oil. In this manner the cast-iron at the moment the decomposition of the oil takes place absorbs oxygen and a brown surface of oxide is formed on the surface which adheres very firmly and acquires a good polish, so that the surface of the cast-iron assumes a bronze-like appearance.

Bronze-like Surface on Iron or Steel.—A very fine bronze-like surface, and one that will prevent rusting, may be produced on iron or steel as follows: The object to be acted upon must be cleansed, so as to take off all oxidation or other impurity. It is then exposed for two or three minutes to the action of the vapors of a heated mixture of hydrochloric acid and nitric acid in equal

proportions, at a temperature ranging from 550° to 650° F. After the objects have cooled, they are to be rubbed over with vaseline, and again heated until the vaseline begins to decompose. This treatment with the vaseline has to be repeated once. Should a lighter coloring than bronze be desired, it can be produced by mixing acetic acid with the other acids. In using the above-named chemicals great care should be observed in handling and preserving.

To Give Ground Steel Objects the Appearance of Gold or Good Bronze.—First remove all fatty matter and dirt from the steel object by washing in turpentine, benzine, or petroleum, then heat and apply a light gold varnish, which, when dry, is coated with the clearest and best copal lacquer. In this manner an elegant gold color of various shades is obtained, according to the more reddish or yellowish color of the varnish.

To Bronze Tin.—Prepare two solutions: one of 1 part ferrous sulphate (green vitriol), 1 part cupric sulphate (blue vitriol), and 20 parts of distilled water; and the other of 4 parts verdigris and 16 parts vinegar. Thoroughly cleanse the article by means of a clean brush dipped in a fine earth and water, and after thoroughly drying, apply to both sides a light coat of the first solution by means of a brush. After drying, the article presents a blackish appearance. The second solution is then applied with a brush until the article acquires a dark copper-red color. It is now allowed to dry one hour, and then polished with a soft brush and finely elutriated bloodstone, the surface being frequently breathed upon so as to make the bloodstone adhere. In conclusion it is polished with the brush alone, which is from time to time drawn over the palm of the hand. To protect the bronze against moisture, cover it with a very thin layer of gold lacquer.

To Bronze Zinc.—The zinc to be bronzed must receive an electro-deposit of brass, which is then dipped into a weak solution of sulphate of copper for a red tinge. When dry, wet with a rag dipped into hydrosulphate of ammonia, or a solution of polysulphide of potassium, or protochloride of copper dissolved in hydrochloric acid. After another drying, the surface is brushed over with a mixture of peroxide of iron and plumbago, according to the tint

desired. The brush may be slightly wetted with essence of turpentine, which aids the adhesion of the powder. The raised portions are strongly rubbed to uncover the brass. Afterwards give a coat of colorless varnish. According to another method, the brassed or coppered article is pickled with dilute nitric acid, and then coated with a paste made of 3 parts of peroxide of iron, 2 of graphite, and a sufficient quantity of spirits of wine. After 24 hours this coating is brushed off, and a dark-brown bronze will appear. A bronze of a lighter color is obtained by gently rubbing the brassed or coppered zinc with a soft brush dipped in a solution of 1¼ ozs. of sal-ammoniac, and 3 ozs. of potassium binoxalate in 3½ to 5¼ pints of vinegar.

Silvered Cast-Zinc Articles are colored partially gray and partially black. The dark colors are obtained by coating with a solution of liver of sulphur and also by rubbing with graphite.

To Bronze Electrotypes—Green.—Steep the medal or figure in a strong solution of common salt, or sugar, or sal-ammoniac for a few days, wash in water, and allow to dry slowly, or suspend over a vessel containing a small quantity of bleaching powder, and cover over; the length of time it is allowed to remain will determine the depth of the color.

Brown.—Add 4 or 5 drops of nitric acid to a wineglassful of water, and apply the mixture to the object. When dry, heat the object gradually and equally; the surface will be darkened in proportion to the heat applied.

Black.—Wash the surface of the object over with dilute sulphide of ammonia, and dry at a gentle heat; finally, polish with a hard brush.

To Bronze Medals.—The most simple bronze is obtained by applying upon the cleansed object a thin paste made of water with equal parts of plumbago and peroxide of iron, with a certain proportion of clay. Then heat the whole, and when the object is quite cold, brush in every direction for a long time with a middling stiff brush, which is frequently rubbed upon a block of yellow wax, and afterwards upon the mixture of plumbago and peroxide of iron. This process gives a very bright red bronze, suitable for medals kept in a showcase.

A similar bronze may also be produced by dipping the article into a mixture of equal parts of perchloride and nitrate of sesquioxide of iron, and heating until these salts are quite dry. Then rub with the waxed brush as described.

According to another method, the object is cleansed and covered with hydrosulphate of ammonia. When dry, it is brushed with peroxide of iron and plumbago, and afterwards with the waxed brush. If the object impregnated with hydrosulphate of ammonia is gently heated a black bronze is obtained, which, being uncovered at certain places, produces a good effect.

*Graham's Bronzing Liquids.**—These are used by simple immersions and have a wide range of application, as will be seen from the following three tables:

I. *For Brass* (*by Simple Immersion*).

Number.	Water.	Nitrate of iron.	Perchloride of iron.	Permuriate of iron.	Nitrate of copper.	Tersulphide of arsenic.	Muriate of arsenic.	Potash solution of sulphur.	Pearl ash solution.	Cyanide of potassium.	Ferrocyanide of potassium solution.	Sulphocyanide of potassium.	Hyposulphite of soda.	Nitric acid.	Oxalic acid.	
	pt.	dr.	dr.	pt.	oz.	gr.	oz.	dr.	dr.	oz.	pt.	dr.	dr.	dr.	oz.	
1	1	5	.	..	..	..	..	..	..	..	..	..	..	..	..	Brown and every shade to black.
2	1	.	5	..	..	..	..	..	..	..	..	..	..	..	..	" "
3	1	16	..	..	..	..	..	..	..	..	..	..	16	..	..	Brown and every shade to red.
4	1	..	..	..	..	..	..	.	..	..	..	..	16	1	..	" "
5	1	..	..	..	1	..	..	..	..	..	..	..	..	..	1	Brownish-red.
6	..	..	..	..	..	..	..	..	..	..	..	..	..	3	..	" "
7	1	..	..	..	..	..	..	..	..	..	..	..	..	4	..	Dark brown.
8	1	..	..	..	..	30	..	..	6	..	..	..	..	.	..	Yellow to red.
9	1	..	..	..	..	..	..	1	..	..	..	..	..	..	..	Orange.
10	2	..	..	1	..	..	..	..	..	..	..	..	..	..	..	Olive-green.
11	1	..	5	..	..	..	..	..	..	..	..	2	..	..	..	Slate.
12	1	..	..	..	..	..	..	..	..	..	..	..	20	..	.	Blue.
13	1	..	..	..	..	..	1	..	..	..	..	..	..	..	..	Steel-gray.
14	1	..	..	2	..	..	10	..	..	..	..	..	..	..	..	Black.

* Brassfounder's Manual, London, 1887.

Liquid No. 5 must be boiled and cooled. No. 13 must be used at 180° F. or over. No. 6 is slow in action, sometimes taking an hour to give good results. The action of the others is usually immediate.

II. *For Copper* (*by Simple Immersion*).

Number.	Water.	Nitrate of iron.	Sulphate of copper.	Sulphide of antimony.	Sulphur.	Muriate of arsenic.	Pearl ash.	Sulphocyanide of potassium.	Hyposulphite of soda	Hydrochloric acid.	
	pt.	dr.	oz.	dr.	dr.	dr.	oz.	dr.	oz.	dr.	
15	1	5	..	..	..	..	..	..	..	..	Brown and every shade to black.
16	1	5	..	..	..	..	..	2	..	..	Dark brown-drab.
17	1	..	1	..	..	..	..	..	1	2	" " "
18	1	..	..	2	..	..	1	..	..	..	Bright red.
19	1	..	..	..	1	..	1	..	..	..	Red and every shade to black.
20	1	..	..	..	..	1	..	..	..	..	Steel-gray at 180° F.

III. *For Zinc* (*by Simple Immersion*).

Number.	Water.	Nitrate of iron.	Protochloride of tin.	Sulphate of copper.	Muriate of iron.	Muriate of lead.	Pearl ash.	Sulphocyanide of potassium.	Hyposulphite of soda	Garacine infusion.	Logwood infusion.	
	pt.	dr.	dr.	dr.	dr.	oz.	oz.	dr.	dr.			
21	1	5										
22	1	..	1									
23	1	..	1	..	..	..	..	1				
24	2	..	..	1	1							
25	..	..	..	..	..	*						
26	2	..	..	..	1							
27	..	..	..	..	..	..	..	..	..	*		
28	1	..	..	4	..	..	4					
29	1	..	..	8	..	..	..	..	8			
30	..	..	..	..	..	..	..	..	..	..	*	

* Made to the consistency of cream.

Rockline's Method of Bronzing.—A layer of jeweler's rouge moistened with water is applied by means of a brush to the article to be bronzed, which is then heated to a red heat. By this process the peroxide of iron is reduced to ferrous oxide, and the necessary quantity of oxygen for the formation of a suboxide yielded to the copper. The coating of jeweler's rouge is then removed from the article to be bronzed by pouring a boiling saturated solution of acetate of copper over it, and drying with tufts of cotton.

Walker's Chemical Bronze.—Boil 1 oz. of ammonium carbonate and a like quantity of blue vitriol in 1¼ pints of vinegar until the latter is nearly evaporated. Then add 1¼ pints of vinegar in which has been dissolved ½ drachm of oxalic acid and a like quantity of sal-ammoniac. Place the mixture over the fire until it commences to boil, then allow it to cool, filter and put by in well-closed bottles.

If a medal, etc., is to be bronzed, it is first thoroughly cleansed, then heated and the liquid applied with a badger's hair brush. In a short time boiling water is poured over the medal and, when dry, it is rubbed with a cotton rag dipped in oil and then with dry cotton.

Bronze Powders.—In metal-leaf (Dutch gold) factories the waste resulting in rolling and hammering is used in the preparation of bronze powder. According to the old method the waste was rubbed with a honey or gum solution upon a stone until a mass consisting of fine powder combined to a dough by the honey or gum solution was formed. This dough was thrown into water, and after the solution of the cementing substance the metallic powder was dried, and subjected to oxidation by mixing it with a little fat and heating it in a pan over an open fire until the desired shade of color was obtained. At the present time this laborious and time-consuming method has been much shortened by the use of suitable machines, and of alloys prepared by melting together the metals in suitable proportions for powders which do not require to be colored by oxidation. These alloys are beaten out into thin leaves by hammers driven by steam. The leaves are then converted into powder by forcing them through the meshes of a fine iron-wire

sieve with the assistance of a scratch-brush. This rubbing through the sieve is effected with a simultaneous admission of oil, and the mass running off from the sieve is brought into a grinding machine of peculiar construction—a steel plate covered with fine blunt-pointed needles revolving over another steel plate. In this machine the mass is reduced to a very fine powder mixed, however, with oil. The powder is first brought into water where the greater portion of the oil separates on the surface. The metallic mass lying on the bottom of the vessel is then subjected to a strong pressure, which removes nearly all the oil, the small quantity remaining exerting no injurious influence, but being rather beneficial, as it causes the powder to adhere with greater tenacity to the articles to which it is applied.

In the following table the composition of the alloys for some colors is given:

Color.	Parts.		
	Copper.	Zinc.	Iron.
Yellow	82.33	16.69	0.16
Pale green	84.32	15.02	0.63
Lemon	84 50	15.30	0.07
Copper-red	99.90		
Orange	98.93	0.73	
Pale yellow	90.00	9.60	
Crimson	98.22	0.50	0.56

English Bronze Powders.—The better qualities of English bronze powders consist of copper, 83 parts; silver, 4.5; tin, 8; oil, 4.5; and the poorer qualities of copper, 64.8 parts; silver, 4.3; tin, 8.7; zinc, 12.9; and oil, 3.

Brocade Bronze Powder.—The variety of bronze powder known under this name consists of coarser pieces prepared from the waste of metal-leaf factories, by comminuting it by means of a stamping mill and separating the pieces of unequal size formed first by

passing through a sieve and finally by a current of air. A certain kind of brocade consists, however, not of metallic alloy, but simply of mica rubbed to a fine powder.

Copper Bronze Powder may be obtained by dissolving copper in nitric acid, diluting the solution with water, and then putting into it some small pieces of brightly scoured iron when the copper will be precipitated in a metallic state. The fluid is then poured off, the powder carefully washed, dried and rubbed to heighten its lustre.

Genuine Gold Bronze.—Leaf gold is ground with honey upon a stone until the leaves are broken up and minutely divided. The mixture is then removed from the stone by a spatula and stirred up in a basin of water, whereby the honey is melted and the gold set free; the basin is then left undisturbed until the gold subsides; the water is poured off and fresh quantities added until the honey is entirely washed away. The gold is finally collected on filtering paper and dried for use. Gold bronze occurs in various shades or colors, red, reddish, pale or dark yellow, as well as greenish, the color depending on the varying content of gold or the different mixture of gold with silver and copper. By boiling with various salt solutions or acidulated masses various tones may also be imparted to gold bronze. It acquires a vivid yellow color by boiling in water containing nitric, sulphuric or hydrochloric acid, a reddish color by boiling in a solution of crystallized verdigris or blue vitriol in water, while other shades are obtained by boiling in solutions of common salt, tartar, green vitriol or saltpetre in water.

Metallic gold powder is also obtained by dissolving pure gold in aqua regia and precipitating it again by an electro-positive metal, such as iron or zinc, which in the form of rods is placed in the fluid. The gold is thereby entirely separated. The rods used for precipitation must be scoured perfectly clean and bright. The lustre of the gold bronze may be heightened by rubbing after drying.

Aurum Musivum (*Mosaic Gold*).—This is chiefly used for bronzing copper and brass, plaster of paris figures, etc. It is mixed with 6 parts of bone-ash and rubbed moist on the object. It is best prepared as follows: Melt 2 parts of tin in a crucible, and add with

constant stirring, 1 part of mercury previously heated so far that it just commences to volatilize. When cool grind the amalgam to a fine powder and intimately mix it with 1 part of sal-ammoniac and 1 of flowers of sulphur, and place the mixture in a closed glass flask or retort in a sand-bath. Now heat sufficiently for the vapors to escape, which deposit on the upper part of the vessel. Sublimation being finished take the vessel from the sand-bath and allow it to cool. The upper portion of the contents forms the bronze, which is of a vivid gold-color, while the lower portion consists of sal-ammoniac and cinnabar. On account of the injurious vapors a good draught should be provided for or the operation carried on in the open air.

Brownish Gold Bronze Powders are obtained by exposing to the air and repeatedly moistening with a little water fine, clean iron-filings, then boiling several times, and finally placing the mass in the sun or near a stove. A deep rust-brown powder is thus formed, which becomes still more intensely red by repeatedly adding a little nitric acid during the last boiling. The powder is freed from metallic iron-filings by washing, and dried. By mixing this powder with imitation gold bronze or mosaic gold, bronze powders of the most varying shades may be made.

Genuine Silver Bronze Powder is obtained by grinding waste of silver-leaf in the same manner as given for gold bronze, or by dissolving silver in nitric acid, diluting the solution with water and precipitating the silver as metallic powder by placing a piece of brightly scoured copper-sheet in the solution.

Imitation Silver Bronze Powder is obtained from the waste of imitation silver-leaf, which is rubbed fine, washed and dried. To heighten the lustre of the powder it is again rubbed when dry.

Argentum Musivum.—This is an amalgam of equal parts of mercury, bismuth and tin. It may also be prepared as follows: Melt 50 parts of good tin in a crucible, and when liquid add 50 parts of bismuth, stirring constantly with an iron wire until the bismuth is liquid. Then remove the crucible from the fire and stir in, while the contents are still liquid, 25 parts of mercury and mix the mass until it can be ground upon a stone.

Iron Black.—A bronze-color occurring in commerce under the name of "iron black," and which imparts to the articles treated with it the appearance of bright steel, is finely divided antimony, and may be obtained by precipitating a solution of antimony salt with metallic zinc.

Metallochromy.—Of importance for the metal industry are the beautiful rainbow-colors which may be produced by decomposing upon polished metallic surfaces certain solutions of metallic salts by means of the galvanic current. The metallic surface to be colored is connected to the poles of a powerful galvanic battery, and at a distance of about ½ line is placed the point of a wire connected to the second pole. The colors produced resist more or less friction, are surprisingly brightened by heat, and can stand a considerable degree of it. *To color articles of brass* the following method is frequently used: Prepare a solution of 7 ozs. of caustic potash or of 6 ozs. of caustic soda in 2 quarts of distilled water and boil it together with 4½ ozs. of elutriated litharge in a porcelain dish for ½ hour, constantly replacing the water lost by evaporation. Allow the fluid to settle, then pour off the supernatant clear liquid and preserve it for use. For coloring the fluid is placed in a porous clay cell surrounded in a glass vessel by a fluid consisting of 1 part of nitric acid and 20 parts of water. In this dilute acid is placed a platinum plate and in the fluid in the clay cell the object to be colored, the latter being connected with the negative pole of a battery. The colors appear and change very rapidly. For coloring metals by the galvanic current Matthey uses chiefly lead suboxide and ferric oxide. *Preparation of the lead solution:* Boil 4½ ozs. of litharge, or better, massicot prepared by glowing for 10 minutes, red lead with a solution of 16 ozs. of caustic potash in 1 quart of distilled water. When cool pour off the clear fluid from the undissolved lead oxide and dilute it with distilled water until it shows 24 or 25° Be′. Preserve the fluid in a well-stoppered bottle; when used in the course of time it deposits potassium carbonate. It is then boiled with caustic lime, allowed to settle, and the clear fluid is again used. From time to time it must be again boiled with lead

oxide. *Preparation of the iron solution:* This fluid may be frequently used and in many cases is indispensable, it giving shades which cannot be obtained with lead solution. It consists of an aqueous solution of ferrous sulphate and ammonia, and is prepared by mixing a freshly prepared solution of green vitriol in distilled water free from air with some dilute sulphuric acid and with liquid ammonia until the precipitate at first formed redissolves. The solution thus prepared must be immediately used, it decomposing on exposure to the air, ferric hydrate being separated. The colors produced with this fluid are less durable than those obtained with lead solution, but they are brighter and adhere as firmly as the blue produced on steel by heating. *Preparation of the objects to be colored:* Galvanic coloration should be preferably produced upon a non-oxidizable layer of metal. Gold or a gilt surface, or platinum is especially suitable as a base for the lead oxide separating from the lead solution. Upon platinum it produces a beautiful blue and upon gold, green. The coloration of silver is not so good as that of other metals because its surface becomes immediately dead by oxidation. The better the article to be colored is polished, the brighter the colors obtained; a surface polished with the burnisher becomes more beautiful than one simply polished with ferric oxide. Before coloring each article should be carefully cleansed with an aqueous, or, still better, alcoholic solution of potash. After cleansing the articles must not be touched with the fingers or a cloth. As a galvanic apparatus the inventor employs a small constant battery with two elements.

Weil's Process of Producing Iridescent Copper Precipitates on Iron.—The bath to be used is obtained by precipitating 35 parts of sulphate of copper, or an equivalent quantity of another copper salt by an alkali. The precipitated hydrated oxide of copper is then added to a solution of 150 parts of potassium tartrate, and this mixture to 1000 parts of water. By now adding 60 parts of 70 per cent. caustic soda a clear copper solution is obtained. The object to be coppered is thoroughly treated with a scratch-brush in a bath of a solution of potassium tartrate, then secured as cathode

to the wire of the negative pole and immersed in the bath. The bath gives a well-adhering coating of copper, and can be continually used by replacing the consumed copper by the addition of hydrated oxide of copper; the quantity of copper thus added must, however, not be so large as to exceed the original proportion of hydrated oxide of copper to potassium tartrate. If the latter be the case, an iridescent film of a brass to bronze-color appearance, or of a red, blue, and green color, according to the strength of the current, the duration of the action, and the proportional quantity of hydrated oxide of copper, is formed. These colors are very suitable for industrial purposes, and their effect may be increased by covering certain portions of the article so as to retain the original copper or iron base.

Approved Coatings for Metals.—1. *Black or Colored Coat.* Dissolve flowers of sulphur, about 5 to 10 per cent., in hot oil of turpentine, and gradually add to the solution, with constant stirring, a corresponding quantity of linseed-oil varnish. A black paint is obtained by the addition of solution of asphalt, and any other color desired, by mixing with non-metallic coloring substances. This paint protects the metal coated with it by superficially converting it into sulphur combinations.

2. *Golden Yellow to Brown Coat.*—Place a sufficient quantity of vulcanized rubber in small pieces in an earthen pot, provided with a well-fitting lid, upon glowing coals for 5 minutes; do not remove the lid, as the vapors developed are very inflammable. Pour the melted mass into a tin dish to cool; for the easier removal of the cooled mass, it is advisable to slightly grease the tin dish. Next break up the mass into small pieces, put them in a capacious bottle, pour benzine and rectified oil of turpentine upon them, and shake frequently until all is dissolved except a slight sediment. The fluid poured off from the sediment is an excellent quickly drying varnish, which adheres firmly to metals, and can also be recommended for electrical apparatus.

3. *Black Coat.*—To obtain this, it is first necessary to procure very good and pure platinum chloride. It is best prepared by dissolving platinum in aqua regia (3 parts hydrochloric acid and 1 part

nitric acid). By evaporating the solution, the desired platinum chloride is obtained in the form of crystals, which are dissolved in water. A very beautiful and durable black color is produced upon the articles by dipping them into the solution, or coating them with a sponge moistened with the solution. The same effect is also produced by allowing the crystals to deliquesce in the air, and vigorously rubbing the metal with the moist powder by means of a piece of leather, or smaller articles with the thumb or palm of the hand. To obtain good results, the articles to be blackened must be given a pure metallic surface by turning or in some other manner, be carefully polished, and especially freed from adhering grease by rubbing with Vienna lime, jeweler's rouge, etc. Various shades of color can be produced. The articles treated as above described are dead black; a lustrous *black* color is obtained by polishing with a soft piece of leather moistened with oil, and a lustrous *gray-black color* by polishing with the burnisher or burnishing stone. The color, especially when polished, is very durable, since platinum is not changed by the action of the air. A *black color* may also be obtained by the following process: First brush the article over with nitric acid, and, after drying by heating, brush vigorously to obtain uniformity. Then lay the article over a vessel containing solution of liver of sulphur, and expose it to the action of the developing sulphuretted hydrogen.

4. *Beautiful Steel Gray.*—This coating is obtained by the use of a mixture prepared as follows: Triturate 3.85 grains of lamp-black with 3 to 4 drops of gold-size oil in a dish to a homogeneous coherent mass, and carefully dilute the latter with 24 drops of oil of turpentine. This mixture is especially suitable for optical instruments. Apply a very thin and uniform coating to the articles by means of a fine brush, and allow to dry thoroughly.

New Process of Producing a Gold-colored Coating upon Small Metallic Articles.—The articles of tombac or brass or similar sheet ornamented with sunk ornamentations, inscriptions, names, etc., are first pickled in the ordinary manner, then silvered in an ordinary silver-bath and finally brought into a bath consisting of 6 lbs. of distilled water, 1 oz. sodium hyposulphite and 0.35 oz. of

sugar of lead. Dissolve the sugar of lead by itself in water and add the saturated solution to the solution of the sodium sulphite in the water. Dip the silvered articles in this bath previously heated to from 140° to 167° F. until they have acquired the correct gold-color, which will require 2 or 3 minutes, according to the temperature of the bath. Articles with holes or eyes may be strung upon wires and suspended in the bath; otherwise immersion suffices. When taken from the bath the articles are rinsed in clean cold water, rubbed with dry saw-dust and dried.

Colored Coatings for Metals.—These may be obtained by forming on the surfaces of the metals a coating of a thin film of a sulphide, but the process requires in its application considerable experience. The thorough cleaning of the articles from grease by immersion in boiling potash lye and rinsing in water is absolutely necessary to success. The process is as follows: In a quart of pure water dissolve 1 oz. of hyposulphite of sodium. Stir into this another solution made by dissolving 1 oz. of acetate of lead in a pint of water.

For use heat the solution in a glass or earthenware pan to about 195° F. and immerse in it the metal to be colored. The coating is one of lead sulphide, and its depth of color will depend upon the time the metal is immersed. In a few minutes brass articles of small size may be coated with any color varying from golden-yellow to the tint of clean copper or red gold to carmine, down to dark red; from light analine-blue to bluish-white, then to reddish-white or brown. Steel and iron articles may also be treated and given a fine blue color without the aid of such great heat as is necessary in "bluing" or oxidizing. Copper articles do not, of course, show the lighter tints. If the cleaning is well done the adhesion will be perfect, so perfect, indeed, that the burnisher may be used with impunity; but it is not prudent to use the scratch-brush. Instead of burnishing, however, the surface may be finished by a soft and smooth buff, which will impart a lasting polish.

The solution will not keep long in the heated state, as it deposits its sulphide upon the bottom of the vessel if no metals are present.

A beautiful *red* and *green* coloring can be given to brass articles by omitting the lead and using in its stead an equal weight of sul-

phuric acid. If the immersion continues the red changes to a fine, brilliant green, and then to green and brown, with a splendid iris glitter. This coating is very durable and may be especially recommended.

Coloring of Copper.—All shades from pale copper color to dark chestnut-brown may be produced by a superficial oxidation of the copper. Uniform heating over a spirit flame suffices for small articles, while with larger objects a more uniform result is attained by heating them in oxidizing fluids or coating with an oxidizing paste. Excellent results are obtained with a paste prepared, according to the darker or lighter shade desired, from 2 parts ferric oxide and 1 part graphite, or 1 part ferric oxide and 1 part graphite, and water or alcohol. This paste is uniformly applied with a brush and the article thus treated put in a warm place. The darker the color desired the higher the temperature must be and the longer it must act upon the object. When the heat has sufficiently acted upon the article the dried powder is removed by brushing with a soft brush, and the manipulation repeated in case the shade is not sufficiently dark. The article is finally rubbed with a soft linen rag moistened with alcohol, or brushed with a soft brush and a few drops of alcohol until it is completely dry, and then brushed over with a brush previously rubbed upon pure wax. The more or less dark shade produced in this manner is very warm and resists the action of the air.

Brown Color upon Copper is obtained by the application to the thoroughly cleansed surface of the object of a paste of 3 parts of verdigris, 3 of ferric oxide, 1 of sal-ammoniac and vinegar, and heating until the applied mixture turns black; the object is then washed and dried. By the addition of some cupric sulphate (blue vitriol) the color may be darkened to chestnut-brown.

A brown color is further obtained by brushing to dryness with a hot solution of 1 part of potassium nitrate, 1 of common salt, 2 of ammonium chloride and 1 of liquid ammonia in 95 parts of vinegar.

Red-brown Color on Copper.—Make a paste of 2 parts of verdigris, 2 of cinnabar, 5 of sal-ammoniac and 5 of alum with sufficient

vinegar. Apply this paste to the article and after heating over a coal fire wash and repeat the process.

To Color Copper Blue-black.—Dip the article in a hot solution of 11¼ drachms of liver of sulphur in 1 quart of water, moving it constantly. Blue-gray shades are obtained with more dilute solutions. It is difficult to give definite directions as to the length of time the solution should be allowed to act, since this depends considerably on its temperature and concentration. With some experience the correct treatment will, however, soon be learned.

Cuivre fumé is prepared by coloring the copper or coppered objects blue-black with a solution of liver of sulphur, then rinsing them and finally scratch-brushing, whereby the shade becomes lighter. From raised portions, which are not to be dark, but show the color of copper, the coloration is removed by polishing upon a felt disk.

Steel-gray upon Copper.—To produce a steel-gray color upon copper, dip the clean and pickled articles in a heated solution of chloride of antimony in hydrochloric acid. By using a strong galvanic current the articles may also be coated with a steel-gray precipitate of arsenic in a heated arsenic-bath.

To Color Copper Dark Steel-gray.—For this purpose a pickle consisting of 1 quart of hydrochloric acid, 0.125 quart of nitric acid, 1½ oz. of arsenious acid and a like quantity of iron filings is recommended.

Various Colors upon Massive Copper.—First draw the article through a pickle composed of sulphuric acid, 60 parts; hydrochloric acid, 24.5, and lampblack, 15.5; *or*, of nitric acid, 100 parts; hydrochloric, 1½; and lampblack, ¼. Then dissolve in a quart of water 4.58 ozs. of sodium hyposulphite, and in another quart of water 14.11 drachms of cupric sulphate (blue vitriol), 5.64 drachms of crystallized verdigris and 7.75 grains of sodium arsenate. Mix equal volumes of the two solutions, but no more than is actually necessary for the work in hand, and heat to 167° to 176° F. By dipping articles of copper, brass or nickel in the hot solution they become immediately colored with the colors mentioned below, one color passing within a few seconds into the

other, and for this reason the effect must be constantly controlled by frequently taking the objects from the bath. The colors successively formed are as follows:

Upon copper.	*Upon brass.*	*Upon nickel.*
Orange,	Golden-yellow,	Yellow,
Terra-cotta,	Lemon-color,	Blue,
Red (pale),	Orange,	Iridescent.
Blood red,	Terra-cotta,	
Iridescent.	Olive-green.	

Some of these colors being not very durable have to be protected by a coat of lacquer or paraffine. It is further necessary to diligently move the articles so that all portions acquire the same color. The bath decomposes rapidly, and hence only sufficient for 2 or 3 hours' use should be mixed at one time.

Black upon Copper is produced by a heated pickle consisting of 2 parts of arsenic acid, 4 of concentrated hydrochloric acid, 1 of sulphuric acid of 66° Bé. and 24 of water.

Dead-black on Copper.—Brush the object over with a solution of 1 part of platinum chloride in 5 of water, or dip it into the solution. When dry rub it with a flannel rag moistened with a drop of oil. A similar result is obtained by dipping the copper object in a solution of nitrate of copper or of manganese and drying over a coal fire. The manipulations are to be repeated until the formation of a uniform dead-black.

To Brown Copper.—The copper to be browned is scoured bright with glass-paper, strongly heated over a coal fire, and brushed over with the following solution: Crystallized acetate of copper, 5 parts; sal-ammoniac, 7; dilute acetic acid, 3; distilled water, 85. Finally, rub the article with a solution of 1 part of wax in 4 parts of oil of turpentine.

Browning Liquid for Copper.—Add acetic acid to 11 drachms of spirit of sal-ammoniac until blue litmus paper dipped into the liquid turns red. Then add 5½ drachms of sal-ammoniac and sufficient water to make 2.11 pints. With the fluid thus obtained repeatedly moisten the copper surfaces, rubbing after each application until the desired brown tint is obtained.

Imitation of Genuine Patina.—Articles of copper and bronze exposed for a long time to the action of the air acquire a beautiful brown or green color, which considerably contributes to their handsome appearance. This color is known as *Aerugo nobilis* (noble rust), or *patina*.

Though there are many agents by means of which a layer of patina can be produced upon the bronze, the coating thus obtained cannot compare as regards beauty and durability with the genuine patina.

In order to obtain a coating similar to genuine patina, it is recommended to pursue as nearly as possible the same course by which the latter is naturally formed. By the action of rain, which always contains salts, though in very minute quantity, in solution, the copper is attacked and basic salts of copper are formed upon the surface, which are in the course of time converted by the action of the carbonic acid of the air into basic copper carbonate. The latter has a beautiful green color, and is found in nature as malachite. But besides this process others also take place upon the surface of the article, especially upon that of monuments erected in large cities. The air of the latter is constantly charged with certain quantities of sulphur combinations, originating partially from the putrefaction of excrements, etc., in the sewers, and partially from the combustion of coal containing sulphur. Now, copper being very sensitive to the action of sulphuretted hydrogen, a coating of black cupric sulphide is consequently formed upon the surface of the object, which explains why bronze statues erected in large cities frequently turn black. Dust and fine particles of soot, which deposit themselves especially in the depressions of the object, further contribute to their becoming black. Cupric sulphate has, however, the property of becoming rapidly converted in the air into copper sulphate, from which is again formed copper carbonate, or, so to say, a coating of malachite. Genuine patina, especially that observed on very antique statues, consists, therefore, of a very firmly adhering coating of malachite.

To produce upon a statue a patina-like deposit, brush it over with a very dilute solution of cupric nitrate, to which a small quantity

of common salt solution may be added. When entirely dry, brush the statue with a fluid consisting of 100 parts of weak vinegar, 5 of sal-ammoniac, and 1 of oxalic acid, and repeat the application after drying. In the course of about one week the statue will have acquired a green-brown color, resembling that of genuine patina.

A finer coating, which more closely resembles genuine patina, is, however, obtained by dipping the article into the solution of cupric nitrate, and placing it in a room where a large quantity of carbonic acid is developed, the fermenting-room of a distillery being especially adapted for this purpose, since the high temperature prevailing therein promotes the formation of the green coating. The progress can in this case be watched from day to day, and if in about a week the statue has not acquired the desired coloration, the application of the above-mentioned solution is repeated, this being continued until the desired tint is obtained. The formation of the patina under these conditions taking place in a similar manner as in the open air, a very beautiful and durable coating is obtained.

For coating articles of brass with a *green patina*, apply a solution prepared by dissolving 10 parts of copper in 20 of nitric acid, diluting the solution with 150 parts of vinegar, and adding 5 parts of sal-ammoniac. Allow the articles to stand a few days in the air, and when a green coloration has made its appearance, brush them with old linseed oil, and after a few days rub them with a soft woollen rag. If after the application of the linseed oil the article readily bronzes, a very beautiful patina will soon appear.

There are several methods of giving an agreeable brown patina to medals. It is, however, most readily accomplished by heating the medal in a spirit-flame, and then brushing with graphite. To color a number of medals at the same time, dissolve 30 parts of verdigris and 30 of sal-ammoniac in 100 of water, and add water to the solution until a precipitate is no longer formed. Place the medals without touching each other upon the bottom of a shallow dish, pour the boiling hot solution over them, and allow them to remain until they have acquired the desired tint, which should be a fine brown.

Another Method of Imitating Genuine Patina is as follows: Prepare a paint by triturating copper carbonate with a pale spirit varnish (sandarac varnish, white shellac varnish), and apply it to the article with a brush. The greenish paint remains in the depressions, and presents a patina-like appearance. Ordinary verdigris gives a bluish color, and crystallized verdigris a pale-green color. Various intermediate shades may be obtained by mixing these two copper combinations.

Coloring of Brass and Bronzes.—Most of the directions given for coloring copper are also available for brass and bronzes. Many colorations on brass are effected, however, only with difficulty, and are not entirely successful, as, for instance, coloring black with liver of sulphur. As a pickle for the production of a

Lustrous Black on Brass The following solution serves: Dissolve freshly precipitated carbonate of copper while still moist in strong liquid ammonia, using sufficient of the copper salt that a small excess remains undissolved, or in other words, that the ammonia is saturated with copper. The carbonate of copper is prepared by mixing the hot solutions of equal parts of cupric sulphate (blue vitriol) and of soda, and filtering off and washing the precipitate.

Dilute the solution of the copper salt in ammonia with one-fourth its volume of water, add 31 to 46 grains of graphite, and heat to 95° or 104° F. Place the clean and pickled objects in this pickle for a few minutes, until they show a full black shade, then rinse in water, dip in hot water, and dry in sawdust. The solution soon spoils, and hence no more than required for immediate use should be prepared.

Steel-gray on Brass is obtained by the use of a mixture of 1 lb. of strong hydrochloric acid with 1 pint of water, to which is added 5¼ ozs. of iron-filings and a like quantity of pulverized antimonic sulphide.

Hydrochloric acid compounded with arsenious acid is also recommended for this purpose. The mixture is brought into a lead vessel, and the objects dipped into it should come in contact with the lead of the vessel, or be wrapped around with a strip of lead.

Gray color with a bluish tint upon brass is produced with solution of antimonious chloride (butter of antimony), while a pure *steel-gray* color is obtained with a hot solution of arsenious chloride with a little water.

Straw-color to Brown through Golden Yellow and Tombac Color on Brass may be obtained with a solution of carbonate of copper in caustic soda lye. Dissolve 5.29 ozs. of caustic soda in 1 quart of water and add 1¾ ozs. of carbonate of copper. By using the solution cold a *dark golden-yellow* is first formed, which finally passes through *pale brown* into *dark brown with a green* lustre; with the hot solution the coloration is more rapidly effected.

Color Resembling Gold on Brass.—According to Dr. Kayser a color resembling gold is obtained as follows: Dissolve 8½ drachms of sodium hyposulphite in 17 drachms of water and add 5.64 drachms of solution of antimonious chloride (*liquor stibii chlorati*). Heat the mixture to boiling for some time, then filter off the red precipitate formed, and after washing it several times upon the filter with vinegar, suspend it in 2 or 3 quarts of hot water; then heat and add concentrated soda lye until solution is complete. In this hot solution dip the clean and pickled brass objects, removing them frequently to see whether they have acquired the desired coloration. The articles become gray by allowing them to remain too long in the bath.

Brown Color, called Bronze Barbédienne, on Brass.—This beautiful color may be produced as follows: Dissolve by vigorous shaking in a bottle freshly precipitated arsenious sulphide in spirit of sal-ammoniac, and compound the solution with antimonious sulphide until a slight permanent turbidity shows itself and the fluid has acquired a deep yellow color. Heat the solution to 95° F. and suspend the brass objects in it. They become at first golden-yellow and then brown, but as they come from the bath with a dark, dirty shade they must be several times scratch-brushed to bring out the color. If after using it several times the solution does not work satisfactorily add some antimonious sulphide. The solution decomposes rapidly and should be prepared fresh every time it is to be used.

Bronze Barbédienne on Massive Brass or brassed articles of zinc or iron may be produced as follows: Mix 3 parts of pentasulphide of antimony with 1 part of finely pulverized blood-stone, and triturate the mixture with ammonium sulphide to a not too thickly-fluid pigment. Apply this pigment to the objects with a brush, and, after allowing it to dry in a drying chamber, remove the powder by brushing with a soft brush.

To Color Brass Violet and Corn-flower Blue.—Dissolve in 1 quart of water 4½ ozs. of sodium hyposulphite, and in another quart of water 1 oz. 3¾ drachms of crystallized sugar of lead, and mix the solutions. Heat the mixture to 176° F. and then immerse the articles, moving them constantly. First a gold-yellow coloration appears which, however, soon passes into violet and blue, and, if the bath be allowed to act further, into green. The action is based upon the fact that in an excess of sodium hyposulphite a solution of hyposulphite of lead is formed which decomposes slowly and separates sulphide of lead, which precipitates upon the brass objects and produces the various lustrous colors.

Similar lustrous colors are obtained by dissolving 2.11 ozs. of pulverized tartar in 1 quart of water and 1 oz. of chloride of tin in ½ pint of water, mixing the solutions, heating and pouring the clear mixture into a solution of 6.34 ozs. of sodium hyposulphite in 1 pint of water. Heat this mixture to 176° F. and immerse the pickled brass objects.

Ebermayer's Method of Coloring Brass.—In testing Ebermayer's directions Dr. George Langbein did not always obtain the same results as those claimed by Ebermayer, and his observations are added in parenthesis to every direction.

1. Sulphate of copper (green vitriol), 8 parts by weight; crystallized sal-ammoniac, 2; water, 100, give by boiling a *greenish* color. (The color is *olive-green*, and useful for many purposes. The coloration succeeds, however, only upon massive brass, but not upon brassed zinc.)

2. Potassium chlorate, 10 parts by weight; sulphate of copper, 10; water, 1000, give by boiling a *brown-orange* to *cinnamon-brown* color. (Only a *yellow-orange color* could be obtained.)

3. By dissolving 8 parts by weight of sulphate of copper in 1000 of water, and adding 100 of caustic soda until a precipitate is formed, and boiling the articles in the solution, a *gray-brown* color is obtained, which can be made darker by the addition of colcothar. (Stains are readily formed; upon brassed zinc a pleasant *pale brown* is formed.)

4. With 50 parts by weight of caustic soda, 50 of sulphide of antimony, and 500 of water a *pale fig-brown* color is produced. (Fig-brown could not be obtained, the shade being rather *dark olive-green.*)

5. By boiling 400 parts by weight of water, 25 of sulphide of antimony, and 60 of calcined soda, and filtering the hot solution, mineral kermes is precipitated. By taking of this 5 parts by weight and heating with 5 of tartar, 400 of water, and 10 of sodium hyposulphite, a *beautiful steel-gray* is obtained. (The result is tolerably sure and good.)

6. Water, 400 parts by weight; potassium chlorate, 20; nickel sulphide, 10, give, after boiling for some time, a *brown color*, which is, however, not formed if the sheet has been pickled. (The brown color obtained is not very pronounced.)

7. Water, 250 parts by weight; potassium chlorate, 5; carbonate of nickel, 2; and nickel salt, 5, give, after boiling for some time, a *brown-yellow color* playing into a magnificent red. (The results obtained were only indifferent.)

8. Water, 250 parts by weight; potassium chlorate, 5; nickel salt, 10, give a beautiful *dark brown.* (Upon massive brass a good dark brown was obtained. The formula is, however, not available for brassed zinc.)

To Brighten and Color Brass.—The work to be brightened and colored is first annealed in a red-hot muffle, or over an open fire, allowing the cooling to extend over one hour. The object of the heating is to remove the grease or dirt that may have accumulated during the process of fitting. Soft-soldered work, however, must be annealed before being fitted together, and afterwards boiled in potash lye; this is also done with work having ornamental surfaces. Next, it is immersed in a bath of dilute nitric acid, which may be made

with 2 or 3 parts of water and 1 of acid; but the old acid that contains a small quantity of copper in solution is frequently preferred. The work is allowed to remain in this liquid for 1 or 2 hours, according to the strength of the acid; it is then well rinsed in water, and scoured with sand applied with an ordinary scrubbing-brush, and washed. The pickling bath is made by dissolving 1 part of zinc in 3 of nitric acid of 36° Bé., in a porcelain vessel, and adding a mixture of 8 parts of nitric acid and 8 of sulphuric acid. Heat is then applied, and when the liquid is boiling the work is plunged into it for half a minute, or until the violent development of nitrous vapor ceases, and the surface is becoming uniform. Then it is plunged into clean water, and well rinsed to remove the acid. The ordinary dark grayish-yellow tint, which is thus very often produced, is removed on immersing the work again in nitric acid for a very short time. Then it is plunged into clean or slightly alkaline water, well rinsed to remove the acid, and plunged into warm, dry beech or boxwood sawdust, and rubbed until quite dry. To prevent the action of the atmosphere, it is lacquered; if a green tint is to be produced, the lacquer is colored with turmeric. A dark grayish, but agreeable tint, is obtained by previously immersing the work in a solution of white arsenic in hydrochloric acid, or in a solution of bichloride of platinum, with the addition of some vinegar, or rubbing with plumbago.

Antimony Colors on Brass.—Dissolve ½ oz. of cream of tartar in 1 lb. of hot water, and add 1½ or 2 ozs. of hydrochloric acid and a like quantity of pulverized metallic antimony. By heating the fluid to boiling and immersing the brass objects, the latter acquire a beautiful lustrous color, a gold-yellow tint appearing first, which is succeeded by a beautiful copper-red. By allowing the articles to remain longer in the fluid, the copper-red passes into a beautiful blue-violet, which is finally succeeded by a blue-gray. The colors are constant, and do not change by exposure to the air.

Dead-black on Brass Instruments.—Place about a thimbleful of lampblack on a smooth surface of glass or porcelain, drop 4 or 5 drops of gold size on it, and thoroughly incorporate the same with a spatula. It should form a stiff paste. Use as little of the size as

possible, as an excess will give the coating a glossy, instead of the desired dead finish. Add about double the volume of turpentine; mix with a camel's-hair brush, and apply to the surface to be coated.

Deep Black-blue Stain on Brass.—A stain which produces a deep black-blue layer on brass, and does not require coating with lacquer, is prepared as follows: Dissolve by shaking in a tightly closed vessel about 3½ ozs. of copper carbonate in 1½ pint of strong spirits of sal-ammoniac. The quantity of copper carbonate used must be sufficiently large that a precipitate (hydrated oxide of copper) is formed. The solution thus obtained is diluted with about ½ pint of water, and is immediately ready for use, but as a rule produces, after a few days, a darker and finer color than at the start. The articles cleaned by filing or turning remain in the fluid until they show the desired color.

Lustrous Gold or Green on Brass.—French articles of cast or sheet brass are made of a cheap, pale-colored quality of brass, but they have a beautiful gold color which gives them a fine appearance and makes them more salable. To produce this color the following process is used: Dissolve 4 parts each of caustic soda and milk sugar in 100 parts of water. Heat the solution to boiling for a quarter of an hour; remove the vessel containing the dark yellow solution from the fire and add, with stirring, 4 parts of a cold saturated solution of sulphate of copper. When the fluid has cooled off to about 165° F., and after the separated suboxide of copper has settled, the clean polished articles of brass are introduced into it in a vessel of wood with perforated bottom. In about 2 minutes the golden coloration will probably be dark enough, and the articles are removed, washed and dried in saw-dust. If the articles are permitted to remain for a longer time in the liquid the yellowish color at first developed will change to a lustrous bluish-green and finally to iridescent colors. In order to obtain uniform colorations the temperature must be maintained between 140° and 165° F.

The copper bath may be used repeatedly, and for this purpose should be kept in a well-stoppered flask. When it has become

spent it may be revivified by the addition of 1 part of caustic soda, sufficient water to replace that lost by evaporation, heating to boiling and the addition of 2½ parts of sulphate of copper. If, instead of milk-sugar, glycerine or a bitartrate is used, the colors obtained are not so uniform.

Gold and Orange Stains for Brass.—Dip the articles in a mixture of 3 drachms of caustic soda, 2 ozs. of water and 5½ drachms of moist carbonate of copper. The shades of color appear in a few minutes, and the progress can be readily judged and observed. After obtaining the desired shade of color rinse the articles in water and dry in fine saw-dust.

Beautiful Silver Color on Brass.—Dissolve in a well-glazed vessel 1½ ozs. of pulverized cream of tartar and 2¼ drachms of tartar emetic in 1 quart of hot water, and add to the solution 1¾ ozs. of hydrochloric acid, 4⅓ ozs. of granulated or, still better, pulverized tin and 1 oz. of pulverized antimony. Dip the articles to be coated in the solution heated to the boiling point. After boiling one-quarter to one-half hour they will be provided with a beautiful lustrous coating, which is hard and durable.

New Bronze-color upon Brass and Copper.—A fluid for the production of a brown bronze-color upon brass and copper consists of acetate of copper, 5½ parts; sal-ammoniac, 7; acetic acid, 1; and water, 100. The articles to which this fluid is to be applied must before each application be vigorously heated over a coal fire, the beautiful brown color frequently appearing only after thus treating the article 20 or 25 times. With skilful manipulation the fluid gives very good results. For coating cast-bronze wares a so-called Paris bronze lacquer is sold, which consists simply of a solution of shellac in alcohol with the addition of camphor. A solution of 1 part of shellac in 8 or 10 of alcohol and adding ¼ part of camphor rubbed up with a few drops of oil of lavender gives a lacquer equal to the commercial article.

To Color Copper and Brass.—By dipping a piece of sheet brass, brightly polished and perfectly clean, in a dilute solution of neutral acetate of copper, which should contain not a trace of acid, at a medium temperature for a few moments it acquires an extraor-

dinarily beautiful golden-yellow color. By coating brightly-polished sheet brass a few times with a very dilute solution of chloride of copper it appears deadened and greenish-gray bronzed. By uniformly heating brightly-polished brass so that it can be handled without burning the hands and brushing it over in this state as rapidly and uniformly as possible with a tuft of cotton dipped in a solution of chloride of antimony it acquires a beautiful violet color.

To Whiten Brass and Copper.—Small articles of brass and copper may be whitened by boiling them in a solution of ¾ lb. of cream of tartar, 2 quarts of water and 1 lb. of grain tin or any pure tin finely divided. The tin dissolves in the cream of tartar and is again precipitated on the brass or copper.

To Blacken Small Iron Articles in bulk.—A deep black upon small iron articles is produced by heating them in bulk in connection with oiled saw-dust. For this purpose a strong sheet-iron drum resembling a coffee-roaster is used. It consists of a cylindrical body provided on one end with a handle for turning, and on the other with a funnel in the centre of which is the aperture for charging. For the distribution of the contents strong iron pins are rivetted into the body of the drum. When in use the drum is slowly revolved over a coal or gas fire. The coloring agent consists of an intimate mixture of 10 parts of dry saw-dust and 1 part of linseed oil. The saw-dust thus oiled is shaken in the drum together with the articles to be blackened and exposed to the heat while revolving the drum. The saw-dust undergoing combustion evolves a thick smoke which cannot immediately escape from the drum, it passing out slowly through the aperture in the funnel. This smoke coats the articles with a firmly adhering black color. Care must, however, be had not to expose the articles too long to the heat as otherwise the beautiful black is replaced by a gray color. Hence it is necessary to occasionally examine the articles as to their color. When they show the proper black color the drum is quickly emptied and the contents are spread out upon sheet-iron to cool.

In mixing the saw-dust with oil care must be had not to exceed the prescribed proportions, as with a larger quantity of oil the

saw-dust remains adhering to the articles and is very difficult to remove.

Lustrous Black on Iron is obtained by the application of a solution of sulphur in spirits of turpentine prepared by boiling upon the water bath. After the evaporation of the spirits of turpentine a thin layer of sulphur remains upon the iron, which, on heating the article, intimately combines with the metal.

By another method the cleansed and pickled iron articles are coated when dry with linseed oil and heated to a dark red. If pickling is omitted the coating with linseed oil and heating have to be repeated twice or three times.

According to Mériten a lustrous black on iron is obtained by placing the articles as anode in distilled water heated to 158° F. and using an iron plate as cathode. A layer of ferroso-ferric oxide is formed which, however, can only be obtained in a firmly adhering state upon wrought-iron. The lustre appears by brushing with a soft waxed brush. The current conducted into the bath must only be strong enough to decompose the water without perceptible development of gas.

Brown-black Coating with Bronze Lustre on Iron.—Heat the bright iron objects and brush them over with a concentrated solution of potassium bichromate. When dry heat them over a charcoal fire and wash until the water running off shows no longer a yellow color. Repeat the operations twice or three times. A similar coating is obtained by heating the iron objects with a solution of 10 parts of sulphate of iron (green vitriol) and 1 part of sal-ammoniac in water.

To give Iron a Silver-like Appearance with High Lustre.—Scour the polished and pickled iron surfaces with a solution prepared as follows: Heat moderately 1½ ozs. of chloride of antimony, 0.35 oz. of pulverized arsenious acid and 2.82 ozs. of elutriated blood-stone with 1 quart of 90 per cent. alcohol upon a water bath for half an hour. A partial solution takes place. Dip into this fluid a tuft of cotton and go over the iron portions, using slight pressure. A thin film of arsenic and antimony is thereby precipitated, which is the

more lustrous the more carefully the iron had been previously polished.

To Color Iron and Steel Blue.—Polish and cleanse the article thoroughly with lime and then brush it over with the following mixture: Butter of antimony, 8 parts; fuming nitric acid, 8; and hydrochloric acid, 16. Add the hydrochloric acid very slowly and drop by drop to avoid heating. Apply the mixture to the steel with a rag and rub with green, young oak wood until the desired blue color is produced.

According to Böttger a durable blue on iron and steel may be obtained by dipping the article in a ½ per cent. solution of potassium ferricyanide (red prussiate of potash) mixed with an equal volume of a ½ per cent. solution of ferric chloride.

To Color Iron and Steel Gray.—Polish the article, and coat it with a mixture of butter of antimony, 8 parts, and sulphuric acid, 2 parts. If the color does not turn out handsome enough add a few drops of acetic acid.

Thierault's Process for Coloring Wrought-iron and Steel.—Thierault has invented a process for coloring iron and steel which is intended at the same time to protect the materials from rust and increase the beauty of their appearance. The process has been introduced in practice and has proved useful. In the patent specification the following mixtures are mentioned as suitable for the execution of the process. Fluid *No. 1* contains chloride of mercury and sal-ammoniac; *No. 2* contains chloride of iron, sulphate of copper, nitric acid, alcohol and water; *No. 3*, ferrous chloride besides nitric acid, alcohol and water; and *No. 4*, a weak solution of potassium sulphide. The articles are thoroughly cleansed from grease by immersion in boiling potash lye and rinsing in water, and when dry are twice brushed over with a sponge slightly saturated with fluid No. 1, the second layer being applied when the crust of oxide formed upon the metal is entirely dry and has been rubbed off with a scratch-brush and iron filings and dried with linen. The remaining operations are executed in the same manner. Several layers of fluid No. 2 are next applied and then fluid No. 3, the sponge being thoroughly soaked with the latter,

After drying 10 minutes the articles are thrown into a bath of water at 194° to 212° F., in which they remain for 5 to 10 minutes according to their bulk. When taken out and dried, a few more layers of fluid No. 3 are applied, next a layer of fluid No. 4, and then the articles are again immersed in hot water. When taken from the bath they are wiped off and receive several more layers of fluid No. 3 diluted for this purpose with water. They are then coated with a thin film of olive oil, washed off, immersed in water at 140° F. and, when taken out, rubbed thoroughly first with a woolen rag and finally with a little olive oil. Articles of iron and steel thus treated have a beautiful black, lustrous appearance, especially when polished.

To Blue Small Articles of Sheet-steel.—Dip the articles in a fluid alloy composed of lead, 25 parts; and tin, 1 part, which is melted at the degree of heat required for bluing. The immersion may also be effected in a sand bath heated to and maintained at the required temperature, 572° F. for dark blue, 478° F. for pale blue.

To Blue Small Articles of Iron and Steel so as to leave Portions of them Bright.—The ground and finely polished work is blued, which is best effected over a thick iron plate heated red-hot. In order to insure uniformity the work should not be laid directly upon the plate, but held at some distance over it. The bluing being effected, which will be the finer and more durable the better and more compact the material used in the work, the places which are to remain blue are covered with an oil paint and allowed to dry somewhat. Heated wine vinegar is then poured over the whole, whereby the places not covered by the oil paint immediately become bright. By using the wine vinegar cold it must act about 5 minutes, and the surface obtained is not lustrous but a dead white. After the treatment with vinegar the work is dipped into cold water. The oil paint is then removed, which is readily effected. By this method the bright places retain their polish and show great lustre.

Coloring of Gold.—To impart to articles of gold alloys a color approaching that of chemically pure gold they are treated with a pickle which dissolves the copper and silver on the surface of the

alloy and exposes a layer of pure gold. The composition of this pickle is such that some gold is also dissolved, but it precipitates at once upon the surface of the object, and thus effects the actual coloring. The composition for coloring gold articles consists of decrepitated common salt, 4½ ozs.; saltpetre, 8.11 ozs.; and hydrochloric acid, 6 ozs. The two salts are finely powdered and intimately mixed, and the hydrochloric acid poured over them. The mixture is boiled until chlorine develops. Suspend the gold articles to be colored to a glass-hook or platinum wire and immerse them in the boiling mixture; take them out after 3 to 5 minutes and rinse in boiling water. If the desired color is attained throw the objects into a vessel filled with water, where they remain until all the objects are colored. Then dip them successively in boiling water and dry quickly. If the proper degree of coloration has not been attained repeat the immersion in the bath. By the chlorine developed in the coloring bath chlorides of copper, silver and gold are formed. The latter are, however, in consequence of the content of copper in the alloy, decomposed and the pure gold is precipitated in a more or less thick layer. As in coloring gold it is absolutely necessary to employ a fluid which develops chlorine in abundance, dilute *aqua regia* compounded with a corresponding quantity of common salt may be directly used in case the alloy contains silver. A suitable mixture is as follows: Concentrated hydrochloric acid, 31 parts by weight; concentrated nitric acid, 10; common salt, 20; and water, 40. In this bath the articles must remain only a very short time, as otherwise the surface becomes dead and lustreless.

Bronze-like Patina upon Tin.—Brush the object over with a solution of 1¾ ozs. of sulphate of copper (blue vitriol) and a like quantity of ferrous sulphate (green vitriol) in 1 quart of water, and moisten the dried object with a solution of 3½ ozs. of verdigris in 10½ ozs. of vinegar. When dry, polish the object with a soft brush rubbed upon wax and some ferric oxide. The coating thus obtained being not especially durable must be protected by a coating of lacquer.

Sepia-brown on Tin and its Alloys.—Brush the object over with a

solution of 1 part of platinum chloride in 10 of water, allow the coating to dry, then rinse in water, and, after again allowing to dry, brush with a soft brush until the desired brown lustre appears.

A *dark* coloration is also obtained with a solution of ferric chloride.

Coloring Zinc.—The results obtained by coloring zinc directly according to existing directions cannot be relied on, and it is, therefore, recommended to first copper the zinc and then color the coppering. Experiments in coloring zinc *black* with alcoholic solution of chloride of antimony according to Dullos's process gave no useful results. Puscher's method is better; according to it the articles are dipped in a boiling solution of 5.64 ozs. of pure green vitriol and 3.17 ozs. of sal-ammoniac in 2½ quarts of water. The loose, black precipitate deposited upon the articles is removed by brushing, the article again dipped in the hot solution and then held over a coal-fire until the ammonia salt evaporates. By repeating the operation three or four times a firmly-adhering black coating is formed. To color zinc black with nitrate of manganese, as proposed by Neumanns, is a tedious operation, it requiring to be repeated seven or eight times. It is done by dipping the article in a solution of nitrate of manganese and heating over a coal-fire, the manipulations being repeated until a uniform dead-black is formed.

By suspending zinc in a nickel-bath slightly acidulated with sulphuric acid, a firmly adhering *blue-black* coating is after some time formed without the use of a current. This coating is useful for many purposes. A similar result is attained by immersing the zinc articles in a solution of 2.11 ozs. of the double sulphate of nickel and ammonium and a like quantity of sal-ammoniac in 1 quart of water. The articles become first dark yellow, then successively, *brown*, *purple-violet* and *indigo-blue*, and stand slight scratch-brushing and polishing.

Gray Coating on Zinc is obtained by a precipitation of arsenic in a heated bath of 2.82 ozs. of arsenious acid, 8.46 drachms of sodium pyrophosphate and 1¾ drachms of 98 per cent. potassium

cyanide to 1 quart of water. A strong current should be used so that a vigorous development of hydrogen is perceptible. Platinum sheets or carbon plates are used as anodes.

Green Coating on Zinc.—Zinc articles may be provided with a permanent dark or light green coating resembling enamel as follows: Dissolve 50 parts of hyposulphite of sodium in 500 of boiling water, and at once pour the solution in a fine stream into 25 parts of sulphuric acid. The milk of sulphur that separates will soon ball together in lumps and settle. The hot liquid containing sulphate of sodium and sulphurous acid is decanted and the cleansed zinc placed in it. In a short time it will acquire a very brilliant light-green coating, which only needs to be washed and dried. By exposing it for a longer time to this hot bath the coating grows thicker and the color darker and more brilliant. To insure a fine, brilliant deposit the temperature should not be allowed to fall below 145° F. By dipping the articles thus treated in diluted hydrochloric acid (1 acid to 3 water) sulphuretted hydrogen is evolved, and this enamel-like coating loses its lustre and becomes lighter in color. Aqueous solutions of aniline colors have little effect upon this dull surface, and none whatever on the brilliant coating.

The effect of *marbling* may be obtained by moistening the gray zinc and applying hydrochloric acid in spots with a sponge, then rinsing off and, while still wet, flowing over it an acidified solution of sulphate of copper which produces the appearance of black marble. As this has a dull surface it should be varnished.

By adding 15 parts of chrome alum and 15 more of the hyposulphite to the above solution, the article treated will take on a *brownish* color.

Bronze-color on Zinc.—A sort of bronzing on zinc is obtained by rubbing it with a paste of pipe-clay to which has been added a solution of 1 part by weight of crystallized verdigris, 1 of tartar and 2 of crystallized soda.

Copper-red on Zinc.—Immerse the article in a bath of chloride of copper dissolved in spirits of sal-ammoniac. If the color is to have a yellowish tone add some crystallized verdigris.

Red-brownish Color on Zinc.—Rub with a solution of chloride of copper in liquid ammonia.

Yellow-brown Shades on Zinc.—Rub with a solution of chloride of copper in vinegar.

To Brown Gun-barrels.—Mix chloride of antimony to a creamy consistency with olive oil. Apply the mixture evenly to the heated barrel, allow it to act for 12 to 24 hours, then remove the excess with a woolen rag and repeat the operation. After the second application has acted for 12 to 24 hours, the iron or steel is covered with a bronze-like layer of ferric oxide and antimony, which resists the action of the air and may be made lustrous by brushing with a waxed brush. The sharpening of the chloride of antimony can be effected by adding a little nitric acid to the paste of olive oil and chloride of antimony so as to hasten the operation. *Another formula* is, nitric acid, 1.5 parts; sweet spirit of nitre, 1.5; rectified alcohol, 3; blue vitriol, 6; tincture of chloride of iron, 3; distilled water, 100. Dissolve the blue vitriol in the water, then add the other materials. The burnishing and marking can be effected with the burnisher and scratch-brush. The polishing is best effected by rubbing with a piece of smooth, hard wood, called polishing wood. The barrel is finely varnished with shellac varnish and again polished with the hard-wood polisher. Some prefer the tone of brown produced by blue vitriol, 5 parts; sweet spirit of nitre, 5; water, 100. In any case the surface of the iron must be well cleansed and rendered quite bright; it is then freed from grease by rubbing with whiting and water, or better, with powdered quick lime and water. The browning composition is then put on and allowed to remain 24 hours. It is then rubbed off with a stiff brush. If not sufficiently browned repeat the last process after browning. Clean the surface well with hot water containing a little soda or potash, and, lastly, with boiling water, and dry it. The surface can be burnished and polished. Varnish with tinsmith's lacquer, or with gum shellac, 2 ozs.; dragon's blood, 3 drachms; methylated spirit of wine, 4 pints. The metal should be made hot before applying this varnish, and it will present an excellent appearance. If the varnish is not required to color, but

only to preserve the actual tint produced on the metal surface by the browning fluid, leave out the dragon's blood.

Another Method of Browning Gun-barrels is as follows: Mix 16 parts of sweet spirit of nitre, 12 parts of a solution of sulphate of iron, a like quantity of butter of antimony and 16 parts of sulphate of copper. Let the mixture stand in a well-corked bottle in a moderately warm place for 24 hours, then add 500 parts of rain water and put it away for use.

After the barrel has been rubbed with emery paper and polished, wash it with fresh lime water, dry thoroughly, and then coat it over uniformly with the above mixture; it is best to use a tuft of cotton. Let it dry for 24 hours and then brush it with a scratch-brush. Repeat the coating and drying twice, but in rubbing off for the last time use leather moistened with olive oil in place of the scratch-brush, and rub until a beautiful lustre is produced, then let it dry for 12 hours and repeat the polishing with sweet oil.

To Blacken Damasked Gun-barrels.—The finely polished barrel is coated by means of a woolen rag with a very thin layer of olive oil and then dusted over with hard-wood ash. It is next blackened by heating over glowing coals, and after removal from the fire allowed to cool. When cool it is brushed over with water containing a few drops of hydrochloric acid to the pint and then quickly washed with tow or coarse linen and water. Of the damask thus treated the steel portions become white, while the iron portions appear black. When the operation is finished the barrel is carefully dried and finally rubbed with oil.

To Brown Medals and Coins.—Boil a solution of 2 parts of verdigris and 1 of sal-ammoniac in vinegar, and after removing the scum, dilute with water until it shows only a slight metallic taste and no more white precipitate is formed. Pour off the fluid from the precipitate, bring it to the boiling point as rapidly as possible, and immediately pour it over the polished and clean medals, which should rest with the edges upon a wooden or copper grate on the bottom of the vessel in such a manner that only two points of the periphery touch the bars of the grate. Examine at least every five minutes whether the desired color has been obtained, because by

remaining too long in the fluid the coating becomes scaly and dead. When the medals have acquired an agreeable, red-brown, lustrous color pour off the solution and immediately wash carefully and repeatedly with much water. The solution used, which has become concentrated by boiling, can be again employed by diluting with water and some vinegar. The more dilute the solution, the slower the process of browning takes place; the success of the operation is, however, also more certain. A too strong solution gives a coating which peels off on rubbing.

VII.

CASTING AND FOUNDING.

A METAL to be suitable for casting should possess the following properties: 1. It must be fusible without great difficulty. 2. The casting made of it must show a homogeneous structure. 3. It must fill out the mould sharply and accurately.

Gray pig-iron especially excels in these three points, its applicability for so many purposes depending on these properties; next come the metallic alloys, brass, bronze, gun-metal, type-metal and the various mixtures of lead and tin. It will be readily understood that a thickly-fluid metal cannot penetrate into the fine depressions, and hence, will not fill the mould accurately, this being especially noticeable with tin by itself. On the other hand a mixture of tin, lead and bismuth is very thinly liquid. At a higher temperature white pig-iron becomes pasty, and consequently is not suitable for casting.

Shrinking of Metals in Casting.—With the exception of cast-iron all metals in congealing have the property of contracting, *i. e.*, of occupying a smaller space; a further contraction takes place during the cooling of the congealed metal. The volume of cast-iron increases at the moment of congelation, and consequently the sides of the mould, if yielding as in ordinary sand moulds, will be forced

apart. After congealing the ordinary contraction also takes place in iron.

Hence, all castings when completely cooled off will be smaller than the pattern or the mould. This contraction of the metals in casting is called "shrinking." If, therefore, a casting is to fit other pieces already finished or designed of determined size the pattern must be made larger, in proportion to the shrinkage.

The pattern is the model of which the casting is to be the copy, but an intermediate stage is necessary, namely, the mould, which represents in hollows the projections which must appear on the finished casting. Each of these articles, namely, the pattern, the mould and the casting, is generally made in different materials, each of which is subject to certain alterations in size and shape, dependent upon the degree of heat to which it may be exposed, or upon changes in dryness or moisture. Thus, from the original design or drawing a pattern is made, most frequently in wood, which is then transferred to the mould; this varies in materials according to the nature of the work into which finally the molten metal is poured. In view of these circumstances, and certain known properties of materials at different temperatures, allowances have to be made for shrinkage, etc. The casting itself contracts in cooling to an extent which is pretty well, but by no means accurately ascertained, and for which a regular allowance is made. Thus, in large, heavy castings, $\frac{1}{10}$ inch is added to every foot of length in the pattern, which is found in practice sufficient to allow for the contraction of the metal on cooling, combined as it is with the slight increase in the size of the mould over the pattern. In small castings $\frac{1}{8}$ inch to the foot, or about 1 per cent., is sufficient.

The following table gives the results of practical observations on the shrinkage of metals in casting, and is very simple in application. Thus, a cast-iron girder 20 feet long must have a pattern $0.1246 \times 20 = 2.492$ inches longer than itself, but a pattern 20 feet long would give a casting $0.1236 \times 20 = 2.472$ inches shorter than itself.

Contraction of Metals in Casting.

	Length of pattern.	Contraction.			
		Total in inches.	Per foot of pattern.	Per foot of casting.	
	ft. in.				
Cast-iron girder	21 8¾	3.1	0.1236	0.1246	
" "	16 9	2.05	0.1225	0.1236	
Gun-metal bar	5 4⅝	1.0	0.18568	0.1886	Maximum
" "	5 7 15/16	0.936	0.1653	0.1676	
" "	" "	0.97	0.1713	0.1737	
" "	6 0¼	1.0	0.1616	0.1684	
" "	5 6 1/16	0.92	0.1671	0.1695	
" "	" "	0.90	0.1635	0.1657	
" "	" "	0.88	0.1598	0.1620	
" "	" "	0.84	0.1526	0.1545	Minimum
" "	.....	.....	0.1607	0.1632	Mean of 8
Copper and tin; copper, 1.3; tin, 10.	5 6 3/16	0.895	0.1623	0.1645	Maximum
" " "	" "	0.880	0.1595	0.1617	
" " "	" "	0.880	0.1595	0.1617	
" " "	" "	0.855	0.1550	0.1570	Minimum
" " "	" "	.....	0.1591	0.1612	Mean of 4
Yellow brass	2 9⅛	0.5	0.1811	0.1839	
Copper	7 10⅞	1.54	0.1948	0.1980	Minimum
"	7 5⅛	1.465	0.1972	0.2005	
"	" "	.....	0.1972	0.2005	Maximum
"	.....	.....	0.1964	0.1996	Mean of 4
Lead (mould)	2 0	0.21	0.1050	0.1059	
Zinc cast in iron	2 0 3/16	0.455	0.2257	0.2301	Minimum
" "	" "	0.465	0.2307	0.2352	Maximum
" "	" "	.....	0.2282	0.2326	Mean of 2

For practical purposes the following may be taken as sufficient approximations:

In locomotive cylinders	= 1/16 inch in a lineal foot.
In pipes	= ⅛ " "
Girders, beams, etc.	= ⅛ in 15 inches.
Engine beams, connecting rods	= ⅛ in 16 inches.
In large cylinders, say 70-inch diameter, 10 feet stroke, the contraction of diameter	= ⅜ at top.
Ditto	= ½ at bottom.
Ditto in length	= ⅛ in 16 inches.

In thin brass	= ⅛ in 9 inches.
In thick brass	= ⅛ in 10 inches.
In zinc	= $\frac{5}{16}$ in a foot.
In lead	from ⅛ to $\frac{5}{10}$ in a foot.
In copper	= $\frac{3}{16}$ in a foot.
In bismuth	= $\frac{5}{32}$ in a foot.
In tin	from $\frac{1}{12}$ to ¼ in a foot.

Easy Rule to Find Approximate Weight of Castings.—Thickness in ⅛ of inches × width in ¼ of inches × length in feet = lbs. weight cast-iron; for lead add to the result one-half; for brass add one-seventh, and for copper one-fifth.

Weight of Castings.—The following table gives the weight of a pattern weighing 1 lb. when cast in different metals:

A pattern weighing 1 lb.	Will weigh when cast in				
	Cast-iron.	Zinc.	Copper.	Yellow brass.	Gun-metal
Mahogany	8	8	10	9.8	10
White pine	14	14.5	18	17.5	17.8
Yellow pine	13	12.6	16	15.5	16
Cedar	11.5	11.4	14.5	14	14.5
Maple	10	9.8	12.5	12	12.4

Moulding Sand for Castings of Ingot-iron.—This mass serves for the manufacture of dense and smooth castings of ingot-iron, and consists of a mixture of from 1464 to 1831 cubic inches of sharply-burnt, pulverized and entirely pure refractory clay with 61 cubic inches of sugar, 2 quarts of water and $\frac{1}{7}$ quart of paraffine oil. Before use the mixture is several times sifted to insure a uniform distribution of the moisture; an admixture of silicic acid, lime, magnesia or charcoal must be carefully avoided.

To Prevent the Baking of Moulding Sand.—Moulding sand consists chiefly of quartz sand and clay, the latter serving as a cement for the former. The availability of the sand for moulding is dependent on its fineness and the proportion of the above-mentioned constituents. The content of clay, on the one hand,

must not be so large that the sand becomes hard by the slight glowing caused by contact with the fluid metal, and, on the other, must be sufficiently large to impart to the sand the required coherence after moistening and pressing together. The baking of moulding sand is *decreased* by an addition of soot and coal powder, and promoted by an addition of beer yeast, beer, molasses, rye-flour, etc. A content of lime is injurious to moulding sand. In many places available moulding sand is found which need only to be comminuted and sifted to be ready for use. Where such natural moulding sand cannot be had, it may be prepared by mixing 93 parts of pure quartz sand with 7 parts of clay free from lime. Moulding sand which has been used and has partially lost its cementing power can be restored by mixing with fresh sand. Moulding sand should not be stored in the open air, since the finer particles of clay are washed out by the rain.

Moulding and Moulds.—Almost all general machine moulding is done in green sand, which is moulding sand, moistened sufficiently to cause it to adhere; and work in which particular care is to be taken is done in dry sand. This is sand which has been dampened, the same as green sand, and then put in an oven and thoroughly dried, which sets the mould in shape. It is claimed that by thus drying the sand the casting will be saved from sand-holes. Another advantage of dry sand moulding is that the mould can be tipped on end and make the casting endwise to insure soundness, as the pressure of the metal from above causes a solid settlement towards the bottom of the casting. Thus it is claimed by this method that a more solid and sounder casting can be made than by the use of green sand, in which the casting must be done flat, as the sand would not otherwise adhere and the mould would be spoiled. The first step in moulding, after the moulder receives his pattern of the article to be cast from the pattern-maker, is the making of the flask or box in which moulding sand and the pattern are to be placed. This flask is built upon the idea of allowing room for the pattern and moulding sand. The flask is generally a box of pine wood or iron. The white pine flask must be made strong enough to stand the pressure of metal and the weight of

sand in the box. The pine boards are put together with dowel pins, so that when the flask is taken apart it can be easily made up again.

Wooden flasks are made for green sand moulding, but all flasks made for dry sand moulding are made of iron, because these moulds have to be put in an oven and kept there until the sand is thoroughly dry, and the pine boards would not stand the heat. In flasks for both green and dry sand moulding there are bars sticking from the upper and side interior surface of the flask to hold the sand in place. Some of these bars have little pieces set on at right angles to the end, or little hooks, which aid in holding the sand in place in addition to the adhesiveness caused by the dampening in the green sand and afterwards by the drying or baking of the dry sand mould. These bars extend from the interior surface of the flask to within a few inches of the pattern, and without them the sand would probably not hold its form after the pattern is withdrawn. The flask is generally made of three or more pieces so that it can be taken apart and the pattern taken out after the mould is formed. The flask having been prepared, a certain quantity of the wet or dampened moulding sand is taken and rammed down hard into place, and then the pattern is put in and covered up with damp moulding sand, which is also rammed down firm. After the pattern is covered up and the whole interior flask filled up, it is secured and the whole allowed to rest a while until it is thoroughly set and the pattern is taken out, the upper part of the flask and mould replaced, and the mould is ready for the metal. The dry sand flask, after being thoroughly and solidly filled with wet sand, is carried to the oven and baked until the sand is thoroughly dry and set, the time depending on the size of the flask and the amount of sand. Then it is removed, the pattern taken out, and the mould is ready for the casting. The dry sand mould being baked holds together very well, as may be easily understood, but it appears singular that the green sand will hold together, but such is the adhesive powder of the wet sand and the arrangement of the holding bars, that it almost invariably does. The cases of the breaking of moulds because the sand does not hold are not frequent,

and the main loss of moulds comes from the breaking of the flasks, which sometimes give way when the metal is being poured in, owing to the great weight of metal and sand combined, which the flask is not strong enough to sustain. This occurs mainly in large castings, and naturally the losses are very serious, it being oftentimes very difficult to recover the molten metal, which becomes mixed with the sand, and get it in condition for casting again. The casting being generally large, the losses of this character are mostly heavy ones.

Moulds have to be broken sometimes because of the impossibility of removing the pattern without doing so, owing to the bad pattern-making, and in this case both the mould and the pattern are a loss and sometimes a very expensive one.

The green sand moulds are broken up after they have been used once, and most of the dry sand moulds are broken up also, and if further castings are wanted new moulds are prepared. When a number of castings of the same character or description are wanted, and the casting is a small one, it is done by the gate system. In other words a number of patterns are prepared and joined together by a little bar extending one from the other, and the moulds are made from this gate pattern.

The rest of the operation is the same as any casting, and the articles are secured in gate or joined together at a certain point by a bar or bars which can be easily broken, and the rough ends finished off, leaving the articles just as they are wanted. The advantage of this method is that a larger number of small articles can be secured by one gate casting which otherwise would have to be cast separately at the expenditure of much additional labor and time.

The patterns for this gate-casting system are made separately, but with the little bars projecting out in such a manner as to form a continuous bar or connection in the casting. This method of work is very useful in the casting of small articles, and is practised to a great extent by the gray iron foundries. The moulds and flasks for this gate casting are made in exactly the same manner as for other castings.

The flasks for the different moulds are, according to circumstances, made in three or four parts to conform to the joints of the mould, which in turn is based upon the character of the pattern. The joints in the mould, and consequently in the flask, are for the purpose of removing the various parts so as to get the pattern out, and the pattern itself has to be jointed, in order that it may be taken out properly. There are frequently more joints in the flask and mould than in the pattern. The top of the flask, which is always a removable part, is called the cope. This cope is invariably gaggered; that is, it has the bars and hooks above mentioned extending from its inner surface to hold the sand in place. The bottom of the mould is called the nowel, and the pieces, parts, or sides between the cope and nowel are termed the cheeks. According to the style of the pattern the cheeks are few or many; that is, they have few joints or a good many. The cope is of course always removable, and the cheeks are also, to get the patterns out. In very large castings the foundry floor, which is always made of moulding sand, is used for the nowel, and the cope and cheeks are constructed in the flask as usual.

Foundry Flasks.—Fig. 4 (1) is a plan of the section view; Fig. 4 (2) showing a very serviceable and useful style of cast-iron flasks used in some foundries. They are made from band-pulley patterns, and have a flange cast on each edge. No bars are cast in them. Two holes, *A A*, are drilled and countersunk in each flange for the wrought guide-pins *B* (one shown bolted in position at *C*). By this arrangement a drag or cope of any depth can be made by simply placing the pieces on top of each other, and fastening together with bolts and clamps made for the purpose. Crossbars can be fitted in the cope to suit the work. In a certain foundry they have also a large number of square and oblong flasks made in the same order as shown in broken plan, Fig. 4 (3). These flasks are in constant use. The drags of the smaller sizes are turned over on a level sand bed without any danger of their dropping out. Bottom boards are used on the larger ones, unless the work is of such a character as to bed in. The drags, of green and dry sand

mould, four and five deep, are made in a comparatively short time by having these sections to clamp together.

Fig. 4 (4) is a broken plan of another style of square and oblong cast-iron flasks, which are handy in a foundry for general or special work. The lugs *D* are cast plain and drilled by a template, and wrought-iron guide-pins bolted in for the cope. Section Fig. 4 (5) is on a line through Fig. 4 (4) from *E* to *E* (without showing the lug *D*). The joint edge *F* has a strengthening strip cast on it, and the handles *G* are made by placing cores rammed up in core-box, Fig. 4 (6), against the end of the pattern when moulding the flask.

Fig. 4 (7) is the plan of the drag of a flask used more especially on moulding machines, but which are successfully and profitably used on the floor in some foundries. These flasks are made with the sides and ends straight or tapered, as may be required. As the lugs *H H* fit over pins on the moulding machine, which are the counterpart of the pins cast on the cope, it is necessary to have the inside of the lugs smooth, and as near the same size as possible. For this purpose the cast-iron clamp, Fig. 4 (8), is made and planed upon the sides and inside of the ends at *I*. The ends of these clamps or formers at *I* ought to be wide, and long enough to extend into the sand beyond the lugs, so as to prevent a rough place or fins on the points at *J*, which would prevent the flask fitting nicely on the guides of the moulding machine, or the cope-pins working in the drag. The plan is very simple. The flask pattern is of cast-iron, and when moulding it the clamp is set in the lugs, and rammed up with the pattern, and left in the mould when the pattern is drawn out on the plan of any chill.

Fig. 4 (9) is a plan view of the cope of this type of flask. Fig. 4 (10) is an end elevation of Fig. 4 (9), and Fig. 4 (11) is a cross-section of the same broken off at *K*. These views show the style of cast-iron formers or chills that are used to cast the guide-pins in; these pins fit into recesses in the moulding machine, and must be very exact to prevent shifting on the machine, or when the cope-sand drags are closed together. It will be noticed that the chill extends beyond the pin at *L L*, and is also a little deeper at *M M*,

Figs. 4 (10) and 4 (11). This prevents the fins and ragged edges spoken of in connection with the lugs, Fig. 4 (9).

These pins and lugs are made heavy and strong, and as the

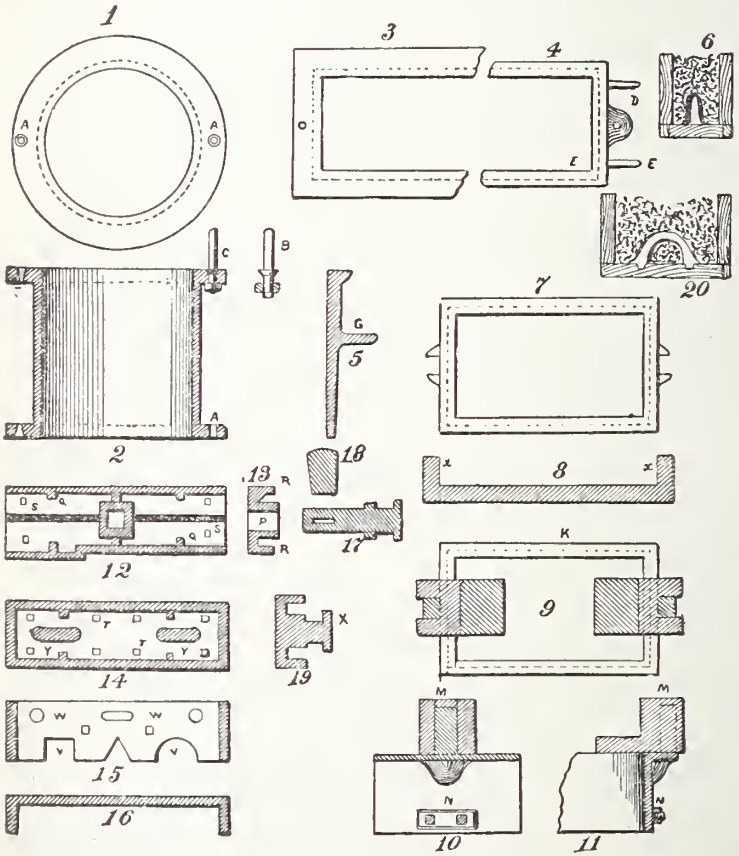


Fig 4.

flasks are cast of soft foundry iron, the bearing or working parts of the pins and lugs have a smooth surface; they fit together very nicely, and do not wear, and are not easily broken off. Wooden

handles *N N* are bolted to the flasks, and if desired for the class of work to be made in them, strengthening strips or bars can be cast across the bottom of the drags, and crossbars of any style cast in the copes (this can also be done in Figs. 4 (3) and 4 (4). Flasks of this pattern made for a moulding machine have been used constantly on the floor for other work, and as they are interchangeable there is no danger of getting the flasks mixed. Fig. 4 (12) is one style of end for a heavier class of cast-iron flasks. The braces *O O* extend from the height of the trunnion-hole *P*, and taper off to the ends; *Q Q* are strengthening brackets for the flanges *R R*, Fig. 4 (13) being a cross-section from *P*. It is not always that both these flanges are cast on, sometimes only on the joint edge of the flask, and often, when the centre-rib brace is used, no flanges are made except at the ends for bolting to wooden sides. The holes *S S* are for bolting to the ends of heavy iron sides, Fig. 4 (14), which have a flange all around the edge, and holes, at *T T*, for bolting iron crossbars shown in side and edge views, Fig. 4 (15 and 16). The various shapes at *V V* will be understood by moulders as being made to suit, and intended to fit, corresponding shapes in the pattern; the holes *W W* are cast in to make the bars lighter, and as many can be made as desirable, so that it does not affect the strength of the bar.

Fig. 4 (17) shows a style of trunnion made of wrought-iron for lifting and swinging heavy flasks. The trunnion is put through the hole *P*, and fastened by driving the key, Fig. 4 (18), into the slot near the end of the trunnion. This leaves a projection on the inside of the flask, and is not near so convenient in any way (whether the flask is round or square) as to cast a good strong trunnion on the flask seen at Fig. 4 (19); or the end of the trunnion *X* can be of wrought-iron and cast fast in the flask.

Y Y, Fig. 4 (14), is another style of handles or loops for heavy flasks. These are better made of wrought-iron, and cast fast or bolted in the sides of the flasks; they can be put in straight or at any angle to suit. For flasks of medium weight a good strong handle of this style can be made in a core, as at Fig. 4 (20), and cast on the sides of the flask. Fig. 4 (6 and 20) are section views

of the straight and loop style of handle rammed up in the core-box, showing them before the core-box is turned over to remove the handle patterns. In the drawings the core-boxes are shown deeper than is really necessary (Robert E. Masters, in "The Western Machinist.")

To Mould Lace, etc., in Cast-iron.—Mr. Outerbridge has succeeded in moulding fine lace in cast-iron, the impression showing the most delicate lines of the pattern. The lace to be moulded must first be carbonized. In place of lace other fine tissues, embroidered ornamentations upon stuffs, leaves, grasses, etc., may also be moulded, previous carbonization being, however, always required. The process is as follows: The respective articles are laid flat upon a layer of pulverized coal upon the bottom of a cast-iron box; another layer of pulverized coal is then sifted upon them. Another layer of patterns may be laid upon this, succeeded by another layer of pulverized coal, and so on until the box is full. The box being closed with a well-fitting lid it is placed in a furnace and heated, at first slowly to expel moisture and gases, until the blue flames disappear. The heat is then increased to a white heat and continued for at least two hours. The box is then taken from the furnace and allowed to cool off gradually, when the tissue is taken out and tested in a gas flame. If carbonization is complete the tissue suffers no change and is ready for casting. It shows great pliancy, the same as is observed in the carbon threads of incandescent lamps. In the first experiments a piece of lace carbonized in the manner above described was laid upon moulding sand, the ends being allowed to project over the edges of the flask to insure against displacement. The fluid iron being poured in, the carbonized lace fixed itself firmly to the sand, and after casting could without difficulty be detached from the iron. Thus several castings can be obtained from one pattern. The impressions are extraordinarily fine and delicate, and could formerly only be obtained by galvanic deposition. It does not matter whether soft gray foundry-pig or white pig is used.

The success of the castings must be chiefly attributed to the peculiarity of iron of possessing under certain circumstances a

tendency of absorbing carbon. In flowing over the carbonized lace the liquid iron evidently combines with the carbon of the pattern, and very likely would completely absorb the tissue if it did not congeal so rapidly. Something similar may be observed with mercury. The latter when poured upon a table runs about in globules without moistening the table, unlike water. But when poured upon a zinc plate it does not run off in globules, but instantly combines with the zinc, moistening it like water. It is, therefore, evident that if another metal, such as brass or zinc, were poured upon carbonized articles, such sharp impressions could not be obtained.

Cores in Heavy Castings.—When cores run through heavy bodies of iron, the hot liquid raises the fusible element of the sand to such a high temperature that the grains fuse together, so that when the casting cleaner tries to get the core out he finds it almost as hard as the iron. A good thing to prevent this fusing of the sand is to mix some sea-coal or blacking in it, and to give the surface of the core a good body of black lead or plumbago blacking. This outside coat of blacking will prevent the liquid iron from eating into the surface of the core sand, and the sea-coal or blacking mixed in the sand burns away and passes off in the form of gas, leaving a porous body between the grains of sand, which assists in preventing its fusion.

In putting rods in such cores as are subjected to a high temperature, it is a good plan to coat them with two or three coats of flour-paste and dry them in an oven as it is put on ; for by doing this the dried paste burns off from the rod and leaves it free to come out of the casting.

Core for Difficult Castings.—The following are instructions for a composition for cores that may be required for difficult jobs, where it would be extremely expensive to make a core-box for them: Make a pattern (of any material that will stand moulding from) like the core required. Take a mould from the same in the sand, in the ordinary way, place strengthening wires from point to point, centrally, gate and close your flask. Then make a composition of 2 parts brickdust and 1 of plaster of Paris ; mix with

water and cast. Take it out when set, dry it and place it in the mould warm, so that there may be no cold air in it.

Casting Without Core.—This mode of casting would, no doubt, be used more if it were not connected with a peculiar disadvantage. Casting without core is executed by pouring the fluid metal (zinc, tin, lead or alloys of these metals) into a mould generally of brass

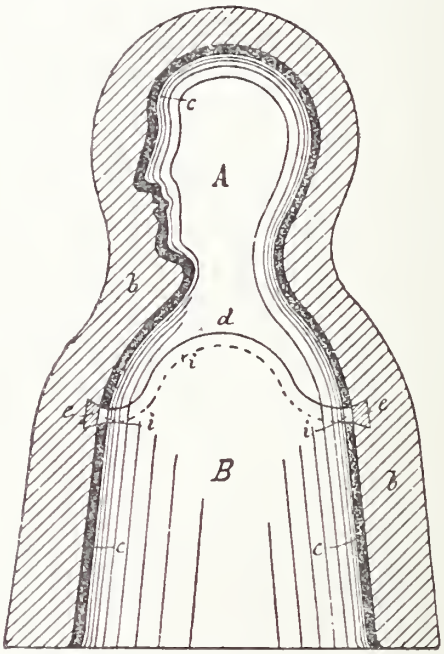


Fig. 5.

with a comparatively large gate, whereby the gate must of course be kept uppermost, just the reverse of the position shown in the illustration, Fig. 5. The mould *b* entirely filled with liquid metal is then more or less quickly inverted, so that it comes into the position shown in the illustration. By not allowing time for complete congelation the larger portion of the metal poured in will

run out, whilst a crust *c* of more or less thickness remains in the mould and forms a casting useful for many industrial purposes.

To obtain solid castings free from blowholes the metal must stand under a certain pressure which is also required for other castings. For this purpose a "dead-head" (riser or sullage piece) is used, and as the dead-head is also hollow after inverting the mould, this portion of the casting is called the "funnel." In the illustration a small bust *A* is given as an example of casting without a core; the lower portion of the finished bust is indicated by the curved line *d*; *B* is the dead-head or funnel which simply serves for making the metal in *A* compact. After removing the casting from the mould the dead-head or funnel *B* is separated from the casting by sawing, filing or other suitable mechanical treatment along the edge of *d*. The metals chiefly used for casting without a core possess, however, the peculiarity of being worked with difficulty, especially zinc and many zinc alloys, fouling the saws and files so that the separation of the dead-head from the casting becomes a difficult matter. This is the chief reason why casting without core is comparatively little in use.

The necessity of removing the dead-head or funnel by sawing, filing, etc., however, is entirely done away with by working in the mould *b* along the edge of *d* a groove *e*. This groove is filled with a material which is a bad conductor of heat but will stand a high temperature, asbestos being especially recommended for the purpose. Now, while the fluid metal when poured in congeals on the metallic walls of the mould, they being good conductors of heat, congelation does not take place along the line of the asbestos, the metal poured in remaining fluid, or at least much more fluid on this point than on other places of the mould. By now inverting the mould the strip *i* lying opposite to the groove *e* filled with asbestos runs out together with the metal filling the mould, and when taking the mould apart the dead-head or funnel *B* will be found separated from the actual casting, or connected with it only by a very thin film which can readily be severed.

Casting Brass-nuts on Screws.—Polish the screw, make a mould on it, with a gate or runner at the end when the mould is hori-

zontal, 1 inch in diameter, 5 inches high, scoop out the top 3 inches diameter levelled down to 1 inch; second, make the gate or runner on the top of screw ½ inch diameter, same height as the other. Take a pricker and prick from the top of the mould to the pattern nut about a dozen holes, after which draw diamonds with the wire from these holes to the sides of the mould on the top. Now part the mould, draw the nut and screw, cut the gates, making the one at the end of nut same as the down one, one inch in diameter; take the screw, smoke it over a gas flame, turning it round, pouring a little oil on it; continue heating till the oil begins to boil. At this stage take a little dry of the parting-sand, which is used to part the mould, sprinkle this all round on the top of the oil, heat now as before to dull red and proceed as before. Remelt the metal, take 3 lbs. of old waste handles free from iron, add to this 9 lbs. of copper, melt both, and when ready for casting add ½ lb. of zinc or spelter, allow it to remain in the fire ten minutes, take it out, add ½ lb. of block tin and ¼ lb. of lead; stir the whole well up. The screw is now red and in the mould; rush the metal in quickly at the gate 1 inch diameter; be sure the metal is hot and it will rise at the other gate to the top of the mould. Be careful at this stage. To take the nut off do not heat it; dress it as before; hammer it cold, heat it—now hold the screw upright, pour on oil at the top of the nut, allow it to cool, catch the nut in vice, apply a lever to the square at end of screw and turn it around.

Casting on to other Metals.—It is occasionally desired to unite other metals by means of cast-iron, or to fix ornamental castings on to light work made of wrought-iron or steel. One well-known application of this process is Moline's invention for the combination of wrought and cast-iron in the manufacture of window-frames. The sash-bars are formed of wrought-iron, rolled of any light and convenient section, suited to receive glass: these bars are united by ornamental cast-iron bosses.

An iron pattern is first made, from which a sand mould is obtained; the wrought-iron bars are cut to the required lengths and placed in the mould with their ends nearly touching; over these

ends the mould of the boss is placed, which must be sufficiently large to cover them so that, when cast on, the bosses shall firmly unite the wrought-iron bars. These windows can be readily made of any usual size or shape, and are easily fixed. They are light in appearance, and combine the strength of wrought-iron with the ornamental character, which can be readily obtained by the addition of cast-iron flowers, scrolls, armorial bearings and other ornaments.

For ornamenting wrought-iron railings, two ways of applying cast-iron may be mentioned. Either the wrought-iron bars may be placed in the moulds and the ornaments cast round their ends, or the ornaments may be cast in green sand moulds, cored out to fit wrought-iron bars, on to which they are afterwards fixed by an alloy of zinc and lead. Lead alone is to be avoided, as it sets up a galvanic action and assists the formation of rust.

In designing cast-iron railings it will be well to adopt outlines in which the metal will not be unfairly strained, by the union of very light and heavy pieces in the same casting. Discard all very fine ornamental work for streets where there is much traffic, as accident or mischief will very shortly spoil the beauty of the work which cannot be repaired. Ornamental cast-iron work of a fine intricate character is only in place where it can be seen to advantage, and is not exposed to violence.

If cast-iron chill-moulds are used for the ornamental castings, the ornaments will naturally be rather brittle; in most cases this will be found of little consequence, but where it is desired to avoid brittleness, the work can be placed in an annealing oven, when the cast-iron will be made into malleable cast-iron without prejudicially affecting the wrought-iron if any is used in conjunction with the cast-iron, as is frequently done.

Ornamenting Wrought-iron by Burning on.—Burning on is occasionally practised for the purpose of ornamenting wrought-iron with scrolls, volutes, or twisted forms. Loam moulds are made, and, when thoroughly dried, are applied to that portion of the wrought-iron which it is wished to burn on to; cast-iron is then poured through the moulds until the wrought-iron is brought to a

welding heat; pouring is then ceased, and the cast-iron, when cooled down, is found firmly affixed to the wrought-iron.

For ornamental cast-iron railings which are designed with comparatively heavy pilasters and bars, having the intervals between them filled in with light ornamental work, the two should not be cast at one and the same time, otherwise the light work will be almost certain to break away from the heavy, owing to the unequal contraction in cooling. The ornamental work should be cast first, of fine, soft, fluid iron, and be provided with small-fitting pieces or lugs at convenient points for fixing to the heavy bars or uprights. Coat these lugs on the fine work with clay and black-wash, place in a sand mould and cast the heavy work round it. By so doing the iron will not be liable to fracture from unequal contraction and expansion.

To Repair Castings by Burning on.—A piece of machine framing, the necks of rolls or a standard which has been broken or found defective may be repaired as follows: First cut away the defective parts down to the sound metal; build a coke-fire round the part of the casting which is to be repaired until it is brought to a bright red-heat, then dust over the surface of the cut metal with powdered glass or borax. Then apply a hollow loam mould of the desired part to the casting, properly secured in position and provided with a hole for the exit of the metal. Pour very hot liquid cast-iron into the mould and allow it to flow away until the cut surface of the original metal of the casting can be felt with an iron bar to have become soft and pasty by contact with the hot liquid iron. Then stop the exit hole and allow the metal in the mould to set. If the operation has been properly performed the casting should, when struck, ring with the same sound as a single good casting, thus showing that the old and new metal are perfectly united.

To Fill up Holes in Castings.—Holes occasionally occur on the surface of a casting, which, although not of sufficient importance to make it advisable to reject or break up the casting, are unsightly. Liquid cast-iron may be poured into such holes, the superfluous metal being removed by an iron straight-edge. It is usually preferred, however, to fill up these cavities with an alloy having a

similar appearance to the cast-iron, but being much more fusible. One such alloy consists of antimony, 69 parts by weight; copper, 16; tin, 2, melted together; to which add afterwards, lead, 13 parts; *another* is, antimony, 65 parts by weight; copper, 16; lead, 13; prepared in the same way.

Bell Founding.—The most important point in the art of bell founding is the proper form to give a bell to obtain the desired tone, which is also dependent on the metal used. In a bell of the usual proportions the thickness of the upper or thin part is one-third of the *sound-bow*, or thickest part. As to the thickness of the sound-bow itself, which is often spoken of simply as the *thickness* of the bell, large bells of a peal are sometimes made as thin as $\frac{1}{16}$ of the diameter, and the small ones as thick as $\frac{1}{10}$ of the diameter; the most effective proportion is from $\frac{D}{12}$ to $\frac{D}{13}$.

In casting peals of bells it is necessary to take rather a wider range, in order to prevent the treble being so small and weak as to be overpowered by the tenor, though care must be taken not to run into the opposite extreme and make the large bells too thin. In calculating the sizes of bells to produce particular notes, and assuming that eight bells are made of similar material, and their sections exactly similar figures, in the mathematical sense, they will sound the eight notes of the diatonic scale, if all their dimensions are in these proportions: 60, 53⅓, 48, 45, 40, 36, 32, 30, which are merely convenient figures for representing the inverse proportions of the times of vibration belonging to the eight notes of the scale. So that if it is required to make a bell a fifth above a given one, it must be ⅔ of the size in every dimension, unless it is intended to vary the proportion of thickness to diameter, for the same rule then no longer holds, as a thinner bell will give the same note with a less diameter.

The reason is that according to the law of vibrating plates or springs, the time of vibration of similar bells varies as $\frac{\text{thickness}}{\text{diameter}}^2$. When the bells are also completely similar solids, the thickness itself varies as the diameter, and then the time of vibration may be said simply to vary inversely as the diameter.

The weights of bells of similar figures vary as the cubes of their diameters, and may be nearly enough represented by the figures 216, 152, 110, 91, 64, 46, 33, 27. The exact tune of a set of bells as they come out of the moulds is a secondary consideration to their tone or quality of sound, because the notes can be altered a little either way by cutting, but the quality of the tone will remain the same forever, except that it grows louder for the first two or three years that the bell is used, probably from the particles arranging themselves more completely in a crystalline order under the hammering, as is well known to take place.

The designing of bells is regulated by certain fixed rules, derived from experience, and which are handed down from one generation of bell founders to another; some makers have their own peculiar mixtures of metal and design of bell, to which they attach particular importance and secrecy, but it is doubtful whether any real advantage has been attained, either in tone or durability, by any of the secret processes as compared with bells carefully designed and cast with proper precautions, and a thoroughly good metal, on the ordinary plan.

Small bells are generally moulded in sand from a metal or wooden pattern, and the sand-mould is dried in a stove.

Large bells are moulded in loam. The core is built in brick on an iron platform, which must have nugs in case the mould is made above ground. This brick core is covered with $\frac{3}{4}$ inch or 1 inch thick of hair-loam, and the last surface washing is given by finely ground composition of clay and brickdust. This latter is mixed with an extract of horse-dung, to which is added a little sal-ammoniac. Upon the core the "thickness" is laid in loam-sand, but the thickness is again washed with fine clay to give it a smooth surface. Ornaments which have been previously moulded, either in wax, wood or metal, are now attached by means of wax, glue or any other kind of cement. If the ornaments are of such a nature as to prevent the lifting of the cope without them, for the cope cannot be divided, the ornaments are fastened to the thickness by tallow, or a mixture of tallow and wax. A little heat given to the mould will melt the tallow, after which the ornaments ad-

here to the cope, from which they may be removed when the cope is lifted off the core. The thickness must be well polished; and, as coal cannot be used for parting, the whole is slightly dusted over with wood ashes. The parting between the core and the thickness is also made with ashes. The cope is laid on at first by means of a paint brush, the paint consisting of clay and ground bricks, made thin by horse-water. This coating is to be thin and fine; upon it hair-loam and finally straw loam is laid.

The crown of the bell is moulded over a wood pattern, after the spindle is removed. The iron or steel staple for the hammer is set in the core, into the hollow left by the spindle. It projects into the thickness, so as to be cast into the metal. The facing of the mould ought to be finished when the cope is lifted off. Small defects may occur, and are, if not too large, left as they are; the excess of metal in those places being chiselled off after the bell is cast. All that can be done in polishing the facing of the mould is to give it a uniform dusting of ashes. When the mould is perfectly dry, it is put together for casting. The core may be filled with sand, if preferred, but there is no harm done if it is left open, for bell-metal does not generate much gas, and there is no danger of an explosion. The cope is in some measure secured by iron, but its chief security is in the strong well-rammed sand of the pit. The cast-gate is on the top of the bell, either on the crown, or if the latter is ornamented, on one side of it. Flow-gates are of no use here; the metal must be clean before it enters the mould; there is no danger of sullage.

Casting Aluminium Bronze.—Aluminium bronze is not an easy metal to cast perfectly until the moulder is familiar with its peculiarities. The great enemies of steel castings, dissolved oxides and gases, forming blow-holes, are here absent. The aluminium removes these impurities from the original copper and by its presence afterwards keeps the bronze free from them. The obstacles which afford most trouble in casting aluminium bronze are the shrinkage in setting and contraction in cooling. These two factors are extraordinarily large, and must be met by provisions made in moulding.

A plumbago crucible is best for melting the bronze, the melt being kept covered with powdered charcoal. It is recommended to coat the stirrers and skimmers used with a wash made of plumbago and a little fire-clay, as the contact of the bronze with bare iron tools cannot but injure its quality. The crucible should not be kept in the fire any longer than is absolutely required to bring the bronze to proper heat for casting. As the metal solidifies rapidly, it is necessary to pour it quickly and to make the gates amply large so that there shall be no "freezing" in the "gates" before the casting is perfectly fed. To obviate the shrinkage as much as possible, the metal is allowed to enter the mould at a temperature not higher than will admit of it running freely. When there is a heavy mass of metal in the shape of an envelope surrounding a core, the contraction upon solidification will cause the metal to split unless the core is made to yield equally with the contraction. Baked sand-moulds are preferable to green sand, except for small castings.

One of the chief difficulties met with in the casting of aluminium bronze is to avoid oxidation in transferring the metal from the crucible or ladle to the mould. If any of the film of oxide which floats on the surface should get into the casting during the pouring, it will appear there like so much dirt, and is apt to cause trouble. The ordinary "skim-gate" will prevent this in the case of small castings, but with large masses the metal is first poured into a receiver, which is connected with and is part of the pouring "gate," but is prevented from entering the mould by means of a plug, which closes up the mouth of the "gate." To illustrate this more clearly, imagine the pouring "gate" shaped like a funnel, into which the metal is first poured. It is prevented from running into the mould by the plug already mentioned. As soon as the dirt has risen to the top the plug is withdrawn, and consequently nothing but the clear metal at the bottom enters the mould. For castings over 50 pounds the metal is poured from a large ladle through a hole in the bottom. Ample facilities should be made for the escape of gases.

The following remarks on this subject are extracted from a paper

on "Casting Aluminium-bronze and Other Strong Metals," by Thomas D. West:

The difficulties which beset the casting of aluminium-bronze are in some respects similar to those which were encountered in perfecting methods for casting steel. There is much small work which can be successfully cast by methods used in the ordinary moulding of cast-iron, but in peculiarly proportioned and in large bronze castings other means, and extra display of skill and judgment, will be generally required. In strong metals there appears to be a "red shortness" or degree of temperature after it becomes solidified, at which it may be torn apart if it meets a very little resistance to its contraction, and the separation may be such as cannot be detected by the eye, but will be made known only when pressure is put upon the casting. To overcome this evil and to make allowances for sufficient freedom in contraction much judgment will often be required, and different modes must be adopted to suit varying conditions. One factor often met with is that of the incompressibility of cores or parts forming the interior portions of castings, while another is the resistance which flanges, etc., upon an exterior surface oppose to freedom of contraction of the mass. The core must generally be "rotten," and of a yielding character. This is obtained by using rosin in coarse sand, and filling the core as full of cinders and large vent-holes as possible, and by not using any core rods of iron. The rosin would cause the core when heated to become soft, and would make it very nearly as compressible as a "green-sand" core when the pressure of the contraction of the metal would come upon it.

By means of dried rosin or green-sand cores we were able to meet almost any difficulties which might arise in ordinary work from the evils of contraction, so far as cores were concerned. For large cylinders or castings which might require large round cores which could be "swept," a hay rope wound around a core barrel would often prove an excellent yielding backing, and allow freedom for contraction sufficient to insure no rents or invisible strains in the body of the casting. To provide means for freedom in the contraction of exterior portions of castings which may be supposed to

offer resistance sufficient to cause an injury, different methods will have to be employed in almost every new form of such patterns. It may be that conditions will permit the mould to be of a sufficiently yielding character, and again it may be necessary to dig away portions of the mould or loosen bolts, etc., as soon as the liquid metal is thought to have solidified. In any metal there may be invisible rents or strains left in a casting through tension, when cooling, sufficient to make it fragile or crack of its own accord, and it is an element which from its very deceptive nature should command the closest attention of all interested in the manufacture of castings.

Like contraction, the element of shrinkage is often found seriously to impede the attaining of perfect castings from strong metals. In steel castings much labor has to be expended in providing risers sufficient to "feed solid" or prevent "draw-holes" from being formed, and in casting aluminium-bronze a similar necessity is found. The only way to insure against the evils of shrinkage in this metal was to have the "risers" larger than the body or part of the castings which they were intended to "feed." The feeder or riser being the largest body, it will, of course, remain fluid longer than the casting, and, as in cast-iron, that part which solidifies first will draw from the nearest uppermost fluid body, and thus leave holes in the part which remains longest fluid. The above principle will be seen to be effective in obtaining the end sought. It is to be remembered that it is not practicable to "churn" this bronze, as is done with cast-iron. A long cast-iron roll, 1 foot in diameter, can by means of a feeder 5 inches in diameter, and a ½-inch wrought-iron rod, be made perfectly sound for its full length. To cast such a solid in bronze, the feeding-head should be at least as large as the diameter of the roll, and the casting moulded about one-quarter longer than the length of roll desired. The extra length would contain the shrinkage-hole, and, when cut off, a solid casting would be left. This is a plan often practised in the making of guns, etc., in cast-iron, and is done partly to insure against the inability of many moulders to feed solid, and to save that labor. A method which has been found to work well in assisting to avoid shrinkage

in ordinary castings in aluminium-bronze was to "gate" a mould so that it could be filled or poured as quickly as possible, and to have the metal as dull as it would flow to warrant a full-run casting. By this plan very disproportionate castings have been made without feeders on the heavier parts, and upon which draw- or shrinkage-holes would surely have appeared had the metal been poured hot.

The metal works well in our ordinary moulding sands, and "peels" extremely well. As a general thing, disproportionate castings weighing over 100 lbs. are best made in "dry" instead of "green-sand" moulds, as such will permit of cleaner work and a duller pouring of the metal, for in this method there is not that dampness which is given off from a green-sand mould, and which is so liable to cause "cold shots." When the position of the casting work will permit, many forms which are proportionate in thickness can be well made in green sand by coating the surfaces of the moulds and gates with silver, lead, or plumbago. From "blow-holes," which are another characteristic element likely to exist in strong metals, it can be said that aluminium-bronze is free. Should any exist it is the fault of the moulder or his mould, as the metal itself runs in iron moulds as sound and close as gold. Sand moulds to procure good work must be well vented, and, if of "dry sand," thoroughly open sand mixture should be used and well dried. The sand for "green-sand" work is best fine, similar to what will work well for brass castings. For "dry-sand work" the mixture should be as open as possible, and, for blacking the mould, use the same mixtures as are found to work well with cast-iron.

To Cast Lead-pipe Free from Flaws.—G. Dolleschal, of Aix-la-Chapelle, uses the following contrivance: A round vessel for the reception of the melted lead terminates in the centre below in a short open tube with an interior diameter equal to the exterior of the lead-pipe to be cast. Through this tube and through the entire vessel, exactly in the centre, runs a long core-tube the exterior width of which is equal to the interior of the lead pipe. By a driving gear the vessel can be moved in an exactly straight line from below to above. It is first brought upon the bottom plate of the entire arrangement so that the short tube is closed below. The melted

lead is then poured in and the vessel moved slowly upwards so that the lead has time to congeal in the annular space between the short tube and the core-tube, whilst it remains fluid in the vessel. The lead-pipe thus gradually grows from below to above until the lead in the vessel is exhausted or the upper end of the core-tube is on a level with the upper portion of the vessel.

Dense and Flexible Copper Castings are obtained by adding cryolite and sugar of lead to the copper after it is melted. The proportions are as follows: Pulverized cryolite, 2 lbs.; and sugar of lead, 8½ ozs. to 200 lbs. of copper; a further addition of 2 lbs. of borax being also advisable. The quantities of the additions may be varied according to circumstances. The mixture of cryolite and sugar of lead, with or without borax, is added after the copper is melted. When the compound is entirely melted, which will be the case in 10 to 15 minutes, the melted copper is poured into the mould.

Wrought-iron (or Mitis) *Castings.*—When wrought-iron is heated to a high temperature it does not pass quickly into the fluid state, but for a large increase of temperature above the point at which it first softens it will remain thick or mushy. At a very high temperature it can be made sufficiently fluid to pour into moulds, but the castings thus made are notably unsound and weak. It was discovered by Mr. Wittenstroem, of Stockholm, working with the co-operation of Mr. L. Nobel, of St. Petersburg, that if a small amount of aluminium is added to a charge of wrought-iron which has been heated until pasty, the iron immediately liquefies and can be poured into castings having all the properties of wrought-iron except fibre, and as sound as if of cast-iron. These castings were called "Mitis" castings because of their softness in contrast with cast-iron castings.

The details of the production of Mitis castings are as follows: As the raw material to operate on, wrought-iron, scrap or mild steel are equally suitable. It was found that some of the best results are to be obtained by using Swedish scrap iron or English hematite iron, that is, materials containing less than 0.1 per cent. of phosphorus, which is a very injurious ingredient if present in

much larger quantity. Using a mixture with poorer quality of iron, with phosphorus running up to 0.15 per cent., good results may still be obtained—that is, the castings still compare favorably with ordinary malleable castings. In using scrap steel, which is necessarily low in phosphorus, it was found that manganese interfered with the production of good castings, a result rather unexpected. Since almost every melter devises various mixtures of his own, as circumstances permit, it is but natural that the best features of the Mitis process are found united with some other old-established practices. Thus in one Mitis plant in the United States the mixture for melting was composed of: Mitis scrap, 35 per cent.; hematite muck bar, 35; wrought-iron punchings, 12⅔; soft steel scrap (0.1 per cent. carbon), 12⅔; white pig-iron, 3; ferro-silicon (10 per cent. silicon), 1; ferro-aluminium (6 per cent. aluminium), ⅔. It seems that in this charge the melter used a little white iron as a flux, which would probably introduce 0.1 per cent. of carbon; then the virtues of ferro-silicon for making sounder castings are utilized by adding 0.1 per cent. of silicon to the charge; lastly, 0.04 per cent. of aluminium was introduced.

In general it may be said that if iron free from impurities is used, very good castings are obtained; if iron is used with a large percentage of phosphorus, proportionally brittle and unsatisfactory castings result.

The ferro-aluminium used should be, for similar reasons, free from any considerable amount of such impurities as generally injure wrought-iron.

Since the castings are almost identical in composition with the charge of iron melted, the following analyses of Mitis metal, made by Mr. Edward Riley, will show the range of material or mixture to which the process has been successfully applied:

Raw material.	Carbon.	Silicon.	Phosphorus.	Manganese.
Hematite bar.....	0.067	0.161	0.068	0.022
Swedish scrap.....	0.053	0.044	0.077	0.027
Refined iron.....	0.130	0.124	0.137	0.014

Table Continued.

Raw material.	Carbon.	Silicon.	Phosphorus.	Manganese.
½ Staffordshire iron ½ Swedish scrap	0.130	0.035	0.150	0.026
⅔ Staffordshire iron ⅓ Hematite bar	0.070	0.093	0.194	0.014
Staffordshire iron.....	0.106	0.080	0.250	0.014

The above figures are percentages; sulphur was present in all as a trace. The first in the table, those low in phosphorus, gave the best castings, the last the poorest; with over ¼ per cent. of phosphorus the castings were brittle.

The charge of wrought-iron is placed in covered crucibles and brought to a temperature of about 2200° C., at which heat it just loses the solid and assumes the pasty condition. If it were desired to cast the iron without adding aluminium it would be necessary to superheat it several hundred degrees above this point, not only to give it the desired fluidity but also to permit it being carried about the casting shop. It is during this superheating that a large part of the gases contained in the molten iron are absorbed. If, therefore, the charge is treated with aluminium immediately on reaching the melting point, the effect is such that this superheating with its accompanying deterioration of the iron is rendered unnecessary. This is possible for the reason that on adding ferro-aluminium sufficient to introduce 0.05 to 0.1 per cent. of aluminium the charge immediately liquefies, and is so far from its setting point that it can be removed from the furnace and poured into numerous moulds, retaining all the time its exceptional fluidity. The metal acts just as if it had been superheated several hundred degrees, but this has been accomplished without leaving it in the furnace for half an hour or so, thus attaining an economy in fuel which is not to be ignored. When the crucible is taken from the furnace the charge is perfectly *dead melted*, lies quiet in the crucible, evolves no gas, and teems like molten silver. It is cast in either

sand or iron moulds, and on account of its fluidity does not require large heads to bring the castings up sharp and show the finest impressions of the mould. The material being primarily wrought-iron, the castings do not have to be annealed before using. The thinnest or most complicated castings, which it would be almost impossible to forge in wrought-iron, can be produced, thus furnishing difficult forged pieces at not much greater expense than ordinary castings. Mitis castings are, in short, objects cast of molten iron yet having all the desirable properties of wrought-iron.

Casting Stereo-plates by the Paper Process.—Lay a sheet of tissue paper upon a perfectly flat surface, and paste a piece of soft printing paper on to the tissue paper, pressing them very flat and even. Oil the form of type, lay the paper on it, and cover with a damp rag; beat the paper evenly into the type with a stiff brush, then paste on it a piece of blotting paper and repeat the beating-in process, after which several other layers of soft, tenacious paper must be pasted on and beaten in in the same manner; back up the paper with a piece of cartridge paper. The whole must then be dried at a moderate heat under a slight pressure. When quite dry, brush over the face of the paper mould with plumbago or French chalk. When this is done it is ready for the matrix. This is a box of the size required for the work, the interior of which is type-high. This is called the gauge, and lifts out to insert the paper mould, and is regulated by hand to the size of the plate required. This being placed inside, the lid is shut down and screwed tight, with the end or mouthpiece left open. The metal is poured in at the orifice, and as it is mounted to swing, the box is moved about so as to throw the metal well down and make a solid cast. Then water is dashed on the box, the screw-bar unshackled, the lid lifted, the plate taken off, and the paper mould is ready for use for another casting.

Another Stereotype Process.—The stereotyper first dries the form of types upon an iron steam-table. The form is then partially unlocked, and a hand-brush is rubbed over the surface of the types, cleansing them preparatory to placing over the entire form a sheet or sheets of thin bank-note paper of the finest quality, previously wetted to insure the required pliability. This paper being laid

evenly over the types, the workman takes a long-handled brush, made of short, stiff bristles, with which he beats the wet paper evenly, forcing it into all depressions of the types, taking care not to break the paper. The work being finished, a dampened sheet of thicker, more ordinary paper is placed over the first. This is also brush-hammered down upon the types, and followed by another sheet of paper thinly coated with a preparation of whiting and starch. Again the brush is used to beat this home, after which a brown-paper backing is put on, and then the form of types, covered by the before-mentioned sheets of paper, is trundled to another steam-table, where it is slid under a powerful screw-press, several blankets folded over it, and all firmly held down until the paper matrix is dry-hardened, or "cooked," as the workmen express it. The papering process occupies three or four minutes, the cooking about twice as long. The matrix is now peeled off from the form, and prepared for casting by sifting it over with finely powdered borax, which, with a soft brush, is thoroughly rubbed into the sunken surface left by the types. The surplus borax having been removed, the matrix, which now resembles hard but pliable pasteboard, is ready for the casting box, which is made of iron, either straight or curved, to suit the press-bed. Handle-irons hold the matrix in its proper place, at the exact distance, about half an inch, necessary for the thickness of the stereotype plate, which is made by pouring a quantity of hot type-metal into an open end of the casting box. This metal, dropping between one surface of the casting box and the sunken surface of the matrix, fills up the latter without burning it. A few moments are allowed for cooling, and then the matrix is stripped from the warm plate, which is subsequently prepared for the press by trimming down all thick lines, or chiselling away any superfluous metal, paring off the edges, filing, and otherwise treating the stereotype after the usual manner. Circular saws driven by steam and hand-cutting machinery of various kinds are used in finishing, the whole operation of stereotyping occupying from 15 to 20 minutes. A second plate may be obtained from the original matrix in about 2 minutes, and almost any number of castings can be taken by careful workmen.

Manufacture of Chilled Wheels.—The following is a brief description of the largest establishment for the manufacture of chilled wheels in the United States, and the manner in which the work is advanced from stage to stage: The foundry, which is of course the most important portion of the whole works, is a fine building, with two lines of rails running down its whole length, except opposite the furnaces. The rails are laid to a gauge of about 10 feet, and upon them are placed 12 light travelling cranes, with a platform attached to the centre-post, and upon which the man working the crane stands and controls its movements, both in hauling the moulds and ladles, and in moving the crane from place to place upon the line, the crane being geared for travelling. The floor of the foundry is so laid out that there is room on either side of both pairs of rails for a row of moulds, and in the centre of the building is a path about 4 feet wide. Against one side of the building, and in the centre of its length, are five cupolas, three of 4 feet 6 inches internal diameter, and two smaller ones of 18 inches in diameter. The former are employed in melting the iron for the wheels, the latter chiefly for experimental purposes. The three cupolas are tapped into converging channels, all running into one large tipping reservoir, from which the small ladles are supplied. The blast to the cupolas is furnished by a vertical blowing engine, with two blowing cylinders, one at the top of the machine and one at the bottom, with the steam-cylinder between the two.

The mixing of the irons for the cupola is the most important and difficult operation in the whole course of manufacture. Besides the steel-scrap nothing but charcoal pig-iron is employed, and of this from twelve to twenty different kinds, all of the highest class, are used in varying proportions. But these mixtures have to be altered frequently, owing to irregularities in the nature of the metal, and daily tests are made, with a view of ascertaining what changes, if any, have to be introduced into the next day's work. The proportions of the mixture being decided upon, the cupolas are charged, a ton of coal being first put into the bed of each furnace. The charge is then carefully loaded upon trucks upon a weighing platform. Piles of the various pigs are placed in their proper order around the

truck, and there is a drum upon the weighing machine, on which a sheet of paper is placed, and the weight of each different pig, in proper order, is written upon it. For instance, the workman commences with 250 lbs. of coal in his truck; he then places 125 lbs. of old steel rails, 125 lbs. of cinder pig, 350 lbs. of old wheels, and so on through the long list of charcoal pig-iron employed, the old material being placed at the bottom of the furnace. The weighing platform is so arranged as to record the accumulating weights as the drum revolves, bringing before the workman the name and quantity of each successive ingredient, which he takes from its respective heap before him. As soon as it is loaded, the truck is raised to the top of the cupola by an hydraulic lift. The moulds, when ready, are placed down the building in four rows, one on each side of the two lines of rail upon which the cranes run. The patterns used are almost all in iron, and the chills in the moulds are of cast-iron. One workman can, on an average, mould ten wheels a day, but all failures in the casting, arising from any carelessness in moulding, are charged to him on a rapidly increasing scale.

Before the metal in the cupola is ready to run, a charcoal fire is lighted in the receiver before spoken off, in order to warm it, and also that when filled the metal may be covered with charcoal and oxidation checked. In a similar manner the ladles, of which there are a very large number employed, have burning charcoal placed in them, and they are internally coated in the usual way. These ladles are cylindrical pots made of sheet-iron and mounted each on a pair of wheels for facility of transport. On the sides of each ladle are two sockets, into one of which is placed the end of a handle with forked ends. The ladle being run up to the receiver, the latter is tipped over by the gearing attached to it, and the ladle is charged; it is then brought along the floor to the crane, which takes hold of it; the two square-ended handles before mentioned are inserted in the holes in the axles, the ladle is raised, and the iron poured into the mould. The chilled portion of the wheel sets almost as soon as it comes into contact with the chills, and in a very short time after the casting has been made, the flasks are

removed, the sand knocked away, and the red-hot wheel is placed on a truck to be taken to the annealing pits. This process is one of the most important of the series. If the wheel be allowed to cool in the open air severe internal strains are created which will sometimes be sufficient to destroy the casting, and open air cooling was the chief cause of failure in the early periods of this class of wheel-making.

The annealing ovens are placed at one end of the foundry, and below the floors, the top of the ovens being at that level. Besides these ovens of very large diameters for extra-sized wheels, chilled tyres, etc., there are 48 pits ranged in 6 rows of 8 each. These rows are divided into pairs, each pair of 16 pits being devoted to the reception of one day's production, the period required for annealing being 3 days. By this arrangement, when the last two rows of ovens are charged, the first two rows can be emptied and refilled, so that the work proceeds without interruption and in regular rotation. Two hydraulic cranes, with the booms revolving upon a fixed post, are placed upon the floor and command the whole area occupied by the ovens. The boom of each crane is made double, and upon it runs to and fro a small carriage, from which hangs the chain, carrying at the lower end the hooks by which the wheels are handled. This attachment consists of three arms with flattened ends turned over so as to grip the wheel. The upper ends of these arms are hinged together, and as they tend always to fall inward, they hold the wheel tightly, but by moving a single attachment the arms are thrown outward when it is desired to release the wheel. The motion of the cranes is controlled by one man, fixed stops being provided on the guiding apparatus, so that when the crane is adjusted for filling one oven it remains in that position till it is thrown over to the next.

The ovens or annealing pits are cylinders of sheet-iron $\frac{1}{8}$ inch thick, about 66 inches in diameter, and of sufficient depth to contain easily 18 wheels with cast-iron distance-pieces between them. They are lined with brickwork, and being of considerable depth, they descend into a lower floor. The lower parts are enclosed in a large rectangular chamber, one for each set of ovens. Within

this chamber, and for a short distance above it, fire-brick is used instead of ordinary brickwork as in the upper portions, and within the cylinder a circular foundation of brickwork is set, upon which are placed the wheels on being lowered by the crane. The whole of this weight then is transferred direct to the foundation of the building. At the end of each of the three rectangular chambers already mentioned is a furnace, and each chamber is divided down the whole of its length by a perforated flue; through these perforations the heat from the furnace passes and enters the lower ends of the ovens. These furnaces are required to prevent the too sudden cooling of the castings, but only ¼ ton of coal is burned for each full day's production. Flues leading to the chimney carry off the heated gases from the upper parts of the ovens, and so the process of cooling is thus very gradually carried on, until at the end of three days the wheels are ready for removal. The three large annealing pits mentioned above are somewhat differently arranged. To save room they are not carried down so low as the other ovens, but terminate at a height of about 7 feet above the floor, each being supported upon a central column. When they are used a fire is lighted in the bottom of each pit, the wheels are put in and covered over, and the oven is allowed gradually to cool.

On being removed from the pit the wheels are taken into the cleaning and testing room. Here the sand is removed, and the wheels tested by hammering under a sledge as well as by a small hammer, while the thread is cut at intervals by a chisel. The heavy blows to which the wheel is subjected never fail in detecting faults when such exist, and when they are discovered the wheel is removed to be broken up. About 10 per cent. of the whole production is rejected, but occasionally this proportion is very much higher.

In order to keep the quality of the wheels up to the desired standard, a large number of test pieces are cast every day and submitted to examination. By this means an accurate knowledge of the nature of the wheels, the character of the chill and other points is obtained; the data are carefully recorded, and if the tests are satisfactory the wheels corresponding to the test piece are delivered

into stock. If not they are returned to be broken up. The sound wheels are finally taken to the machine-shop where they are bored, and, if desired, fitted with their axles. The tools, therefore, in this shop are few in number, consisting of three boring machines, a press for forcing the wheels on or for drawing them off the axles, and a number of lathes.

The average life of a chilled cast-iron wheel of first quality is asserted to be 50,000 miles for passenger and 100,000 miles for freight traffic.

Casting of Zinc.—Great difficulties were at first met with in the application of zinc to casting. Since these have been conquered quite a branch of industry has been developed, which furnishes many articles for household and other uses. The extreme brittleness of zinc is no longer a hindrance, since it has been ascertained that it can be overcome by heating the metal to a certain degree (302° to 317° F.). Zinc fills the moulds very sharply, and is, therefore, especially adapted to ornamental and art castings. For larger castings in one piece it is not suitable, as it readily tears on account of strong shrinkage, but the patterns may be divided and the castings united by soldering. From such castings colossal statues can be made, which when coppered by the galvanic process resemble the best bronze castings. For household use zinc is worked into ink-stands, lamps, candlesticks, signs, etc.

The zinc is generally melted in cast-iron kettles and poured out with ladles. Green sand serves as moulding material, though loam may also be used. The sand must be genuine moulding sand, fine and not too loamy; the moulds are not heated. The temperature of melting should not be too high, as otherwise the metal readily oxidizes. Oxidizing may be prevented by covering the metal, while in crucible or ladle, with a layer of common salt or a little hydrochloric acid, which amounts to the same, a coat of zinc oxide being instantly formed on the surface of the melted metal, which effectually prevents further oxidation from the action of the oxygen in the atmosphere. It is an improvement to keep a layer of charcoal on top of the zinc, or a soft metal which can be melted in a ladle; the casting of oxide forms a protection against

oxidation to a certain degree only, while the layer of charcoal tends to reduce the oxide again to its metallic form. Indeed, it is possible to recover lead, tin, zinc and antimony from the "dross" or oxide which gathers in the ladle, it being only necessary to melt the oxide with charcoal, salt and soda, to get it again into useful shape. The dross should be powdered, likewise the salt, charcoal and soda. Mix them together and melt. The soda and salt melt into a pasty mass, and the carbon unites with the oxygen of the dross, leaving the metal free, all but burning off the charcoal. The salt and soda act simply as a flux in reducing the oxides.

For hollow castings the cores are made of sand, but to prevent the danger of tearing on account of the considerable shrinkage of the metal, the scaffolding around which the core mass is moulded must be so arranged that it can be readily withdrawn.

Metallic moulds, if used, must be previously heated. For moulding the ordinary flasks used in brass and iron foundries are employed. To obtain from patterns of larger pieces, castings of slight thickness, the entire pattern is first moulded in the lower part of the box; the top part of the box is then placed in position, the depressed mould is scattered over with coal-dust and the sand in the upper part of the box carefully pressed into the depression of the mould. The upper part of the box is then again removed and sufficient of the moulded sand mass for the intended thickness of the metal scraped off.

Apparatus for Casting Metal, patented by H. A. Brustlein, of Firming, France. The casting ladle *g* (Fig. 6) sits upon a crane and can be moved in a circle as well as up and down; moreover, it can be horizontally shifted to and fro. On the discharge aperture in the bottom is a pipe *a*, which terminates below in an enlarged mouth-piece *b* of burnt clay. This serves the purpose of changing the course of the metal flowing out, and is so arranged that the metal cannot fall vertically upon the bottom of the mould, but must flow over the slightly rising bottom in the mouth-piece *b*. The bottom of the casting mould *h* consists of a comparatively thin metal plate *c*, which rests upon the frame *d*, supported by the plate *f*. The latter in the centre passes into a water-pipe which

feeds the rose *e*, whereby the bottom *c* is cooled. To the plate *f* is secured a bevel wheel *i*, by means of which the entire mould is revolved, whilst the rose *e* remains stationary.

Preparation of Chills for Casting Metal.—To obtain a dense casting in chills, the mould previously made hand-warm is smeared over with old lard and then dusted with soap-stone powder. By this means an expanding layer is formed during casting between the chill and the casting, whereby the gases still present in the interior of the metallic mass are forced to escape through the fluid ingot.

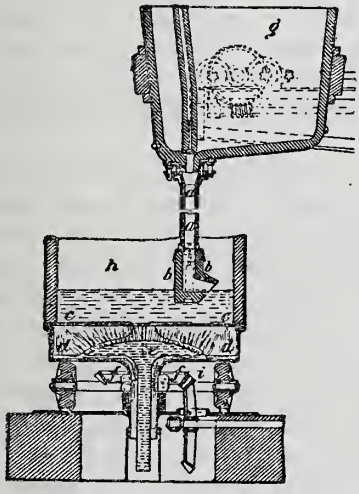


Fig. 6.

Painting and Varnishing Patterns.—As a precaution against defects in the wood, and also as a preservative for the patterns, they are usually coated with varnish or oil paint. Thus their capillary attraction is lessened and their surfaces made smooth and glossy. There is nothing better for these purposes than a moderately hard-drying oil paint, black-leaded over when dry. One mode of coating patterns is to paint them with a thin coat of oil paint, consisting of red-lead and acetate or sugar of lead. Allow this to dry in a warm room, then carefully rub over with sand-paper and finish

with powdered chalk, or a thin coat of less rapidly setting oil paint may be applied, and the surface finished with pumice-stone and very fine glass-paper. Rub well with a soft cloth, then put on a coat of black-lead mixed with beer, applied with a hard brush.

When only one or two castings are required from a pattern, especially if it should be of an ornamental and delicate character, this coating of black-lead and beer may be applied directly to the naked wood of the pattern. This plan answers very well where the wooden pattern is to be employed simply for the production of a metallic pattern. But it is certainly desirable that patterns which have to be used several times should be painted in oil, more especially when they contain joints made in glue.

For large, coarse work, a thin coat of common lead-color oil paint, with slight finish of black-lead put on dry, is a cheap and simple protection.

For wheel patterns the following paint has been recommended as giving excellent results in the moulds and a smooth surface on the castings: A first coat is applied of a paint made of thin drying oil, spirits of turpentine, and pure white-lead mixed with a little crystallized acetate of copper. When dry this is smoothed off with pumice stone, then a second very thin coat of the same paint is applied, with the addition of a little copal varnish. The patterns are then slowly dried, special attention being given that no warping occurs. The paint dries very hard, but after a while, when exposed to wear and handling, it becomes scratched, when it ceases to give such good results as those first obtained. This defect is partially remedied by rubbing the surfaces over with powdered French chalk.

Some patterns, made of rather hard wood, such as dry mahogany, will deliver very well if coated with copal varnish.

Weak shellac varnish is also a capital protection to patterns; it is easily made by dissolving 1½ to 2 parts by weight of shellac in 20 of methylated spirits. The ingredients take some 20 or 30 hours to mix in cold weather, but the mixing may be accelerated by the vessel being placed on a stove or other warm place.

Black-leading of Patterns.—All metallic patterns are much improved in their "delivery" by being finely "black-leaded."

Prior to the application of the plumbago, the surface of brass or gun-metal patterns should be roughened by leaving them wetted with a solution of sal-ammoniac. Zinc, solder, or type metal, or other such soft alloys will take the black-lead at once, if the surface be free from grease and dirt.

Varieties of Wood Most Suitable for Patterns.—The following is a list of the different varieties of wood most suitable for pattern-making, with their specific gravities:

	Specific gravity.
Cork	0.24
American pine	0.37
American fir	0.42
Larch	0.54
Cowrie	0.58
Red Honduras cedar	0.55
Elm	0.55
White poplar	0.34 to 0.53
Willow	0.42 to 0.5
Sycamore	0.60
Lime tree	0.60
Pear tree	0.66
Cherry tree	0.71
Maple	0.75
Apple tree	0.80
Alder	0.80
Beech	0.85
Honduras mahogany	0.81 to 1.06
Boxwood	1.03 to 1.33

To Preserve Iron Patterns from Rusting, and to make them deliver more easily, they should be allowed to become slightly rusty; next, they should be warmed sufficiently to melt beeswax, which is then rubbed all over them, and nearly removed; when cold they are to be polished with a hard brush.

To Mend Patterns.—For mending patterns needing temporary repairs, or for making additions where but one or two moulds are to be made, the following material will be found very useful: Melt together 1 lb. beeswax, 1 lb. resin, and 1 lb. paraffine wax. It is well to note that the beeswax intended is the wax made by the

bees, and not the wax made by the wholesale dealers. When the genuine article is used, this mixture will be found very useful for making additions to patterns, small temporary patterns, and for a variety of purposes in the pattern shop.

Glue for Pattern-makers.—Pattern-makers mix with their glue some good thin-drying linseed oil, in the proportion of about 1 part of oil to 4 of water. The oil is added to the glue, and well stirred in whilst hot. This glue is scarcely affected by moisture, and makes a strong, sound joint, although it does not set hard and glossy like ordinary glue.

Improved Method of Treating Steel for Casting.—This method consists in passing melted steel or iron through a bath or filtering medium of a purifying and deoxidizing alloy of less specific gravity than either steel or iron, such bath or filtering medium rising and forming a stratum or film on the surface of the melted steel or iron while in the cupola from which it is subsequently tapped. The filtering medium is obtained from aluminous iron ore containing from 10 to 12 per cent. of titanium. It is claimed that the effect of passing the steel as it melts through this deoxidizing layer is to clear it of impurities, especially those of a gaseous character, and the resulting castings are free from honeycombs and blowholes. The steel can be reduced to the mildest temper by annealing.

VIII.

CEMENTS.

Iron Cements or Rust Joints.—These cements contain as an essential constituent iron filings and turnings which, as well as the iron surfaces to be united with such cement, are quickly oxidized by the addition of sal-ammoniac, salts, etc., whereby the cement increases in bulk, and, consequently, a complete filling up of the joints is effected. They serve for closing joints on iron pipes, vessels, plates, etc., for cementing iron to iron, or iron to stone.

I. *Iron Cement which Stands Red Heat.*—Iron filings, 4 parts; pulverized fat clay, 2; and finely powdered pieces of Hessian crucibles, 1. The ingredients are mixed and moistened with salt water. Care must be had not to add too much salt, as otherwise the latter would fuse and run from the joints. In using this cement for joining pipes which are to lay in the fire, it is put between the flanges of the pipes, and pressed together by screws. It can be heated only when dry and hard.

II. *Cement for Uniting Iron Surfaces and Filling in Joints.*—Mix 100 parts of iron filings, free from rust and not larger than rape seed, ¾ part of coarsely powdered sal-ammoniac, and ½ part of flowers of sulphur; moisten the mixture with urine and beat it, with repeated moistening, until it becomes heated, dry, and brittle. In this state it is placed in the joints, and forced in as tightly as possible with chisel and hammer, whereby it again becomes moist and soft. Finally, the joints are filled up evenly, and allowed to dry two days, when, as an indication of good cementing, separate black drops must appear upon the hardened crust. The cement does not adhere to tarred kettles or dirty and greasy joints. To keep it, it is rammed into an iron pot and water poured over it. For use, pour off the water, add to the mass taken out sufficient iron filings to give it the necessary consistency, and pour the water back into the pot. The stronger and quicker the cement rusts in the joints the better it acts. The proportions used vary, however, very much. For instance, *a.* Iron filings, 30 parts; sal-ammoniac, 1; sulphur, 1. With this composition the danger of progressive rusting is, however, greater on account of the larger quantity of sal-ammoniac in proportion to iron filings; *or*, *b.* Pulverized cast-iron turnings, 50 parts; sal-ammoniac, 2; flowers of sulphur, 1; *or*, *c.* Pulverized iron filings, 100 parts, and pulverized sal-ammoniac, 2 parts. The mixtures are kept in well-closed boxes in a dry place, for use moistened with urine, and applied as mentioned under II. The cemented places must be heated only when entirely dry.

III. *For Blowing Engines, Blast Pipes, Hot-blast Stoves, etc.*—Mix iron filings, 15 parts; clay, 1; and common salt, 1, with equal parts of vinegar and water, or with urine, to a cement.

IV. *Chenot's Iron Cement.*—Iron reduced from iron ores by hydrogen-gas is kneaded with clay or gypsum. An addition of urine, ammonia, or vinegar very much accelerates the hardening of this cement.

V. *For Gas Retorts and for Connecting of Parts of Iron Exposed to Heat.*—Mix thoroughly 26 lbs. of iron filings, 4½ lbs. of cement, 2 lbs. of gypsum, 7 ozs. of sal-ammoniac, and 5¼ ozs. of sulphur with 1 pint of vinegar, and stir into the mixture some warm water. If the cement is good, small brown bubbles are formed on the surface in drying. Articles joined with this cement must be protected from continued moisture, as otherwise the cement swells and bursts the articles.

VI. *For Smearing Over Joints of Iron Water Reservoirs.*—Mix iron filings with wine vinegar or dilute sulphuric acid (1 part acid to 30 water), and press the mass into the joints; *or*, mix 2 parts of iron filings and 1 of green vitriol to a paste with wine vinegar.

VII. *For Cementing Joints or Cracks in Iron Stoves.*—Mix coarse iron filings, clay, sand, salt, and cow-hair with fresh blood; *or*, clay, beechwood-ash, and some salt with water.

VIII. *For Air-tight Oven Doors.*—Intimately mix 120 parts of iron filings, 2 of pulverized sal-ammoniac, 8 of powdered feldspar, and 1 of flowers of sulphur, and make the mixture into a paste with water. This cement must be used at once.

IX. *For Fastening Iron Rods, Cramps, Hooks, etc., Especially in Stone.*—Make into a paste 3 parts of plaster of Paris and 1 part of iron filings with water or glue water. *According to another direction*, 7 parts of plaster of Paris to 1 of iron filings are used. If, however, the articles to be cemented are to remain white, the iron filings are omitted, and only 7 parts of plaster of Paris and 3 of white of egg with a sufficient quantity of water are used.

It is frequently very difficult to cement articles of iron together so that the cemented places remain tight, even in the fire, to prevent fluids from permeating. If one of the above-described cements of iron filings, sulphur, and sal-ammoniac is used for the purpose, it becomes almost always necessary to tighten the screws in a short time on account of the cement slagging together, which is some-

times very unhandy. Under certain circumstances the cement may also be attacked by the fluid in the apparatus, which of course would cause leakage. Furthermore, the articles joined together easily warp in the great heat or expand in the fire, which causes the cement to give way or to crumble. In such cases packing with iron has proved very effectual. The process is as follows: The articles to be made tight are first made bright by pickling or filing; a disk of bright wrought-iron of the exact shape of the parts to be joined and moistened with vinegar is placed between them and the screw or rivet tightened.

Cement for Iron.—The following mixture has been successfully used for the cementing of iron railing tops, iron gratings to stoves, etc., in fact, with such effect as to resist the blows of a sledge-hammer. This mixture is composed of equal parts of sulphur and white-lead with about $\frac{1}{6}$ part of borax, the three ingredients being thoroughly incorporated together, so as to form a homogeneous mass. When this composition is to be applied, it is wet with strong sulphuric acid and a thin layer of it placed between the two pieces of iron, these being at once pressed together. In five days it will be perfectly dry, all traces of the cement having vanished, and the work having every appearance of welding.

To Cement Iron to Iron.—Mix powdered cast-iron bore chips, 60 parts; sal-ammoniac, 2; flowers of sulphur, 1; and stir the mixture into a stiff paste by adding water. The cement must be used while fresh.

Cement for Fastening Iron Articles in Stone.—Mix good plaster of Paris, 7 parts; iron filings, 1; and stir the mixture into a paste with water. This cement dries very quickly.

Cement for Repairing Defective Places in Castings.—One part of black pitch and 1 of rosin are melted in a crucible, and a sufficient quantity of fine iron filings added to form a stiff mass, which is allowed to become cool. The defective place is heated, a piece of the cement laid upon it and pressed down with a hot iron.

Cement for Iron Stoves.—Mix with sufficient water to form a stiff paste, wood ashes, 10 parts; clay, 10; burnt lime, 4.

Cement for Mending Iron Pots and Pans.—Take 2 parts by

weight of sulphur and 1 of fine black-lead. Put the sulphur in an old iron pan, holding it over the fire until it begins to melt, then add the black-lead; stir well until all is mixed and melted; then pour out on an iron plate or smooth stone. When cool break into small pieces. A sufficient quantity of this compound being placed upon the crack of the iron pot to be mended, can be soldered by a hot iron in the same way a tinsmith solders his sheets. If there is a small hole in the pot drive a copper rivet in it and then solder over it with this cement.

Cement for Making Joints.—I. Mix ground lead with as much finely powdered red-lead as will make it the consistency of soft putty.

II. Mix equal parts of white-lead and red-lead, and add as much boiled linseed oil as is required to give it the proper consistency; *or*, make boiled linseed oil and red-lead mixed into a putty. These cements are used for making metallic joints sound. The following cements are cheaper:

Grouvelle's Oil Cement.—Mix thoroughly red-lead, 1 part; white-lead, 2½; perfectly dry clay, 2 (all finely pulverized), with boiled linseed oil.

Stephenson's Oil Cement.—Litharge, 2 parts; lime fallen to a powder, 1; and fine sand, 1, are mixed to a stiff paste with hot linseed oil. The cement is used while fresh and warm.

Serbat's Mastic.—Finely pulverized sulphate of lead is pounded together with 1 part of old linseed oil in a suitable apparatus. Repeat the operation twice, adding each time 1 part of finely pulverized pyrolusite. It is then preserved in a stone vessel closed with wet bladder. *Another direction for preparing this mastic* is as follows: Triturate 5 parts of zinc oxide and 5 of sulphate of lead with about 4 of linseed oil, then add gradually 10 parts of finely ground pyrolusite and a like quantity of colcothar, and pound the whole in a cast-iron mortar with an iron pestle, adding gradually 100 parts more of pyrolusite and a like quantity of colcothar. The cement is good when sufficiently thick, and at the same time so flexible that it can be rolled out between the fingers without

breaking. If the cement has become hard add some more oil and work it thoroughly with the iron pestle.

Marteaux and Robert's Cement.—This cement may be used for pipes, steam-engine cylinders, etc. It is prepared from pyrolusite, 100 parts; graphite, 12; white-lead, 5; red-lead, 3; and clay, 3. The ingredients are pulverized, sifted and mixed. To 7 parts of the mixture add 1 part of boiled linseed oil and make the whole into a paste, which is heated in a sheet-iron pan and then vigorously pounded so that it becomes soft, after which the alternate heating and pounding is twice repeated.

Diamond Cement.—This cement is recommended for steam-apparatus, steam-boilers, etc., since, when hard, it adheres firmly to the metallic surface and does not shrink. According to Hager it consists of linseed oil varnish, 16 parts; litharge, 16; whiting, 15; and prepared graphite, 50. As the graphite very much impedes the drying in of the linseed oil at an ordinary temperature, the mass can be preserved for a long time in a plastic state.

Glycerin Cement for Iron.—According to Banthoff a very durable fire-proof and water-proof cement for cementing together and tightening even very large iron articles, for instance, cracked boilers, is obtained by working equal parts of red-lead and litharge to the consistency of glazier's putty with concentrated glycerin.

Fire-proof and Water-proof Cement.—To 4 or 5 parts of clay thoroughly dried and pulverized add 2 parts of iron filings free from oxide, 1 of peroxide of manganese, ½ of sea salt and ½ of borax. Mix these ingredients thoroughly and render them as fine as possible, then reduce them to a thick paste with the necessary quantity of water, mixing intimately. It must be used immediately. After application it should be exposed to heat, gradually increasing almost to a white heat. This cement is very hard, and presents complete resistance alike to a red heat and boiling water. *Another method is as follows:* To equal parts of sifted peroxide of manganese and pulverized zinc-white add a sufficient quantity of commercial soluble glass to form a thin paste. This mixture, when used immediately, forms a cement quite equal in hardness and resistance to that obtained by the first method.

Cement for Electrical or Chemical Apparatus.—A good cement for this purpose may be prepared by mixing 5 lbs. of resin, 1 lb. of wax, 1 lb. of red ochre and 2 ozs. of plaster of Paris, and melting the whole at a moderate heat.

Acid-proof Cement.—Make a concentrated solution of silicate of soda, and form a paste with powdered glass. This simple mixture will sometimes be found invaluable in operations of the laboratory where a luting is required to resist the action of acid fumes.

To Cement Thin Metal-sheets.—Dissolve isinglass cut into small pieces in little water at a moderate heat and add a small quantity of nitric acid, the proper proportion being determined by experiment. With too much nitric acid the cement requires weeks for drying and with too little it does not adhere well.

To Unite Glass and Brass.—Melt 5 parts of resin and 1 of wax and stir into the melted mass 1 part of burned ochre and ¼ part of plaster of Paris; *or*, melt together 4 parts of pine resin and 1 of wax and stir into the melted mass 1 part of elutriated brickdust or chalk. Apply warm to the heated surfaces.

To Fasten Metallic Mountings upon Glass, Porcelain, etc.—Dissolve 2 parts of glue of a good quality in water, heat the solution over a coal-fire and add 1 part of good linseed oil varnish and ½ of Venetian turpentine. The cemented articles must remain tied together for 40 to 60 hours.

Cement for Fastening the Metal Parts upon Glass Lamps.—Resin, 12 parts; strong lye, 16; water, 20; plaster of Paris, 20. The resin is boiled with the lye until it is entirely dissolved and, when cold, forms a tenacious solid mass. This is sufficiently diluted by adding the water and the plaster of Paris is then carefully worked in. This cement is insoluble in petroleum.

To Cement Metal Plates on to Wooden Boxes.—Melt together 6 parts of resin and ¼ of linseed oil and stir into the melted mass 1 part of burnt ochre and ½ part of plaster of Paris.

To Cement Iron to Wood or Stone.—Melt together 4 parts of black pitch and 1 of wax and stir 1 part of brickdust into the melted mass.

To Fasten Metals on Wood.—Prepare a thick solution of glue

and stir into it finely ground chalk until the mass has acquired the required consistency. For fastening metals, especially copper, to sandstone the following composition may be used: Work together 7 parts of white-lead, 6 of litharge, 6 of bole, 4 of powdered glass and 4 of linseed oil varnish so as to form a plastic mass.

Cement for Fastening Metal upon Glass.—To secure metal to glass in a safe and quick manner the use of the following cement is recommended: Intimately mix 100 parts by weight of pulverized white litharge and 50 of dry white-lead and work it with a mixture of 3 parts of boiled linseed oil and 1 of copal lacquer to a plastic mass. The cementing itself is very simple. The lower surface of the metal is coated with the cement, pressed upon the glass and the excess of cement removed with a suitable instrument. The cement dries rapidly and becomes very hard.

Cements for Fastening Metal Letters upon Glass, Marble, Wood, etc.—I. Mix copal varnish, 15 parts; boiled linseed oil, 5; oil of turpentine, 5; and glue, 5. The glue is dissolved by placing the mixture in a water bath. When solution is complete 10 parts of slaked lime are added.

II. Mix 15 parts of a varnish prepared from sandarac and white resin with 5 parts of linseed oil, boiled with litharge, and 5 parts of oil of turpentine. To this add 5 parts of marine glue, and after dissolving this mixture on a water bath add 10 parts of flake white and white-lead.

III. Mix 15 parts of copal varnish prepared with an addition of resin and 5 parts of oil of turpentine with 2 parts of powdered isinglass, 5 of sifted iron filings and 10 of washed clay or ochre.

IV. Mix 15 parts of copal varnish prepared with gum lac, 5 of linseed oil boiled with litharge, 8 of solution of caoutchouc in tar oil, 7 of tar oil with 10 of Roman cement and plaster of Paris.

To Cement Glass into Metal.—To cement the glass portions into metallic cases, as is frequently required, for instance in the manufacture of physical and optical instruments, etc., the following practically tested directions are recommended:

I. Melt carefully 160 parts by weight of finely pulverized colophony, 40 of white wax and 80 of colcothar; add to the melting

mass 20 parts by weight of Venetian turpentine, remove the mass from the fire and stir the finished cement until cold with a wooden spatula. Apply the cement warm.

II. Use a good quality of sealing wax, which should, however, not be too brittle. Any brittleness can be immediately removed by the addition of some Venetian turpentine. In cementing glass into metallic cases the glass as well as the metallic casing must be carefully heated to the melting point of the sealing wax.

III. Carefully mix shellac with a like quantity of finely powdered pumice and apply warm.

IV. To fasten metallic or glass articles for optical glasses so that in polishing they remain in a fixed position use a cement consisting of a mixture of 10 parts of pitch and 1 of white wax.

Cement for Fastening Brass to Glass.—For cementing brass on glass the following receipt will be found to answer very well: Take resin soap—made by boiling 1 part of caustic soda and 3 parts of resin in 5 of water—and knead it into half the quantity of plaster of Paris. This cement is used largely for fastening the brass tops on glass lamps. It is very strong, is not acted upon by petroleum, bears heat very well and hardens in one-half to three-quarters of an hour. By substituting zinc white, white-lead or slaked lime for plaster of Paris it hardens more slowly. Water attacks only the surface of this cement. Of course, as it sets shortly after mixing, only as much as may be needed for immediate use should be made at one time.

To Fasten Leather upon Iron.—Apply a coat of lead paint, either white or red lead, to the iron. When dry cover the coat of paint with a cement prepared as follows: Soak glue of the best quality in cold water until soft; then dissolve it in vinegar at a moderate heat, add one-third of its volume of white oil of turpentine, and after thoroughly mixing apply the cement while warm with a brush and press the leather upon it. *Another method is as follows:* Digest 1 part of crushed nut-galls for 6 hours with 8 of distilled water and strain the mass. Soak glue in its own weight of water for 24 hours and then dissolve it. The warm infusion of galls is spread upon the leather and the glue solution on the roughened

surface of the warm metal; the moist leather is pressed upon it and, when dry, it adheres so firmly that it cannot be removed without tearing.

To Fasten Paper-labels to Iron.—Rub the place where the label is to be fastened with an onion cut in half and then stick on the label with paste, gum or glue. The vegetable mucilage of the onion adheres firmly to the iron and combines with the paste on the paper to a mass which does not crack off and stands heating.

Cement for Fastening Labels on Polished Nickel.—Dissolve 400 parts by weight of coarsely powdered dextrin in 600 of water, add 20 of glycerin and 10 of glucose and heat the mixture to 194° F.

Another Mode of Preparation is as follows: Stir 400 parts by weight of dextrin with water, dilute the mass by a further addition of 200 parts by weight of water, add 20 of glucose and 10 of aluminium sulphate and heat the mass in a steam-bath to 194° F., whereby the mass, which is at first thick, becomes clear and thinly fluid. Both kinds of cement are well suited for the purpose, though the first deserves the preference.

To Cement Forks and Knives in their Handles.—I. Mix 1 part of brickdust and 2 of pulverized colophony. Fill the cavity in the handle with the mixture and push in the previously heated tang of the blade.

II. Melt together 4 parts of colophony and 1 part of sulphur and stir into the melted mass iron filings, fine sand or brick-dust. Use in the same manner as in I.

III. *To Secure Forks and Knives in Silver Handles.*—Melt 2 parts of pitch and stir 1 part of brickdust into the melted mass. Fill the cavity in the handle with the mixture and push in the tang of the blade.

To Cement with Copper Amalgam.—The metals to be cemented are first made bright by acid, then heated to from 176° to 194° F. and, after applying the amalgam, firmly pressed together. The parts adhere as firmly as if soldered.

Cements for Parts of Machines.—These consist of a mixture of caoutchouc or gutta-percha with filings of iron, steel, copper or brass, or, in the place of the latter, with powdered iron or copper

ores. The caoutchouc and gutta-percha form either essential parts of the mixture or simply serve for cementing the metallic substances together. An addition of sal-ammoniac or another substance, which attacks the metals in the presence of water, serves for the oxidation of the metals in the mixture, thus effecting a firmer union. The ingredients may, if desired, be compounded with sulphur combinations; they are then rolled out and brought into the required shape. The proportions vary according to the purpose for which the cement is to be used.

I. *For Steam-Pipes.*—Caoutchouc, 2 parts; gutta-percha, 1; sulphur, 1; iron filings, 10. Should there be a difference in price, a portion of the caoutchouc may be replaced by gutta-percha and *vice versa;* powdered ores, with omission of a corresponding portion of sulphur, may be substituted for the portion of the iron filings.

II. *Cement for Parts of Copper and Brass.*—The same composition as given under I. is used, the iron being replaced by copper or brass shavings.

III. *For Pipe-conduits not Exposed to Heat.*—Caoutchouc, 4 parts; gutta-percha, 1; sal-ammoniac, 1; sulphur, 1; iron filings, 10.

IV. *For Packing Stuffing-boxes and Pistons of Steam-engines.*—Caoutchouc, 5 parts; gutta-percha, 2; sulphur, 1; powdered graphite, 1; silicate of magnesia, 1; filings of copper, zinc, lead, tin or alloys of these metals, 10.

If the ingredients have been intimately mixed and form a homogeneous mass the cements are well adapted for the purposes mentioned. If one of the cements is to be exposed to the direct action of the fire or a high degree of heat asbestos is to be added to the mixture. For the oxidation of the metals contained in the cements they are exposed to the action of cold or hot water for 1 to 12 hours, according to the thickness of the plates into which they have been rolled. The penetration of moisture into the mass is promoted by mixing with it some fibrous material such as cotton or asbestos.

A Permanent and Durable Joint can be made between rough

cast-iron surfaces by the use of mineral asbestos mixed with sufficient white-lead to make a very stiff putty. This will resist any amount of heat, and is unaffected by steam or water. It has been employed for mending or closing cracks in cast-iron retorts used in the distillation of oil and gas from cannel coal. The heat being applied to the bottom of the retorts, and the temperature of the iron maintained at a bright red heat, after a time the bottom of the retort would give way, the larger portion of the crack being downward toward the fire. The method employed was to prepare the mixture and place it on the top of a brick, then put the brick on a bar of iron or a shovel, and press the cement upward to fill the crack in the iron, holding it for some time until it had penetrated the cavity and somewhat set. Of course, during this operation, the lid was removed from the retort, so that no pressure of gas or oil forced the cement outward until set.

Schiefer's Packing Rings for Manholes and Flanges.—The joining of manholes and flanges is not difficult when there is sufficient time to allow the cement to harden. The case is, however, different when such joints are to be made in a short time and the work is to be at once proceeded with. Hence the use of Schiefer's rings may be recommended, which avoid this evil and allow of an immediate continuation of the work. The rings are made of stout pasteboard, and receive first a ground paint of 100 parts of graphite, 100 of fibrous gypsum, 2 of alum, and 20 of rye flour in 75 of water. The mass is intimately and finely ground, and applied thrice as uniformly as possible to the rings. The rings when completely dry and hard and solid are again three times coated with a paint of 50 parts of graphite, 5 of chemically pure white-lead, ½ of borate of manganese and 20 of good linseed oil varnish, and are then ready for use. They are then again coated with the above composition, which should, however, be of greater consistency and are used in the same manner as rubber or similar rings.

Colored Cement for Repairing Zinc Ornaments.—Soda water glass solution of 33° Bé is intimately mixed with fine whiting and an addition of zinc dust (tutty) to a thick plastic mass, which hardens

in 6 to 8 hours, becomes extraordinarily solid and acquires a gray color. By polishing, after hardening, with an agate it acquires the lustrous white color of metallic zinc, so that defective zinc ornaments and zinc vessels can be durably repaired with it. The cement adheres well also to glass and wood.

Evans's Metallic Cement.—This alloy is obtained by dissolving cadmium amalgam prepared from 25.99 parts of cadmium and 74.01 parts of mercury in an excess of mercury, slightly pressing the solution in a leather bag and thoroughly kneading. By kneading, especially if previously heated to about 97° F., the cement is rendered very plastic and, like softened wax, can be brought into any form. On cooling it acquires considerable hardness.

Cement for Luting Crucible Lids.—Apply a thick paste made from lime freshly slaked to a powder and concentrated solution of borax. Let it dry slowly and then heat in the usual manner.

Cements for Water-pipes.—I. *Cement for Joining Cast-iron Water-pipes* (for use on a large scale). Pulverize and mix 24 parts of Roman cement, 8 of white lead, 2 of litharge and 1 of colophony. Work the mixture into a plastic mass with old linseed oil kept boiling together with one-half its weight of colophony until the latter is dissolved.

II. Mix equal parts of burned lime, Roman cement, potter's clay and clay, all separately dried and ground fine, and knead the mixture with linseed oil.

III. Melt together colophony and tallow, and stir into the melted mass enough finely sifted gypsum to give it the required consistency.

Bismuth Cement for Cementing the Glass Parts on Petroleum Lamps.—This cement is composed of lead, 3 parts; tin, 2; and bismuth, 2.5.

Armenian or Jeweller's Cement.—Dissolve 5 or 6 pieces of gum mastic the size of a large pea in as much spirits of wine as will suffice to render it liquid; in a separate vessel dissolve as much isinglass (previously softened in water, though none of the water must be used) in rum or other spirit, as will make a 2 oz. phial of very strong glue, adding two small pieces of gum-ammoniac, which

must be rubbed or ground until dissolved, then mix the whole at a sufficient heat. Keep it in a phial closely stoppered, and when it is to be used set the phial in boiling water. This cement is effectual in uniting almost all substances, even glass to polished steel.

IX.

CLEANSING, GRINDING, PICKLING, POLISHING.

Cleansing Metals with the Sand Blast.—In large establishments engaged in galvanizing cast-iron without previous grinding, the use of the sand blast in place of the circular wire brush has recently been introduced with great advantage. Articles with deep depressions, which cannot be reached with the scratch-brush, as well as small articles, which cannot be conveniently held in the hand and pressed against the revolving scratch-brush, can only be brought by the sand blast into a state of sufficient metallic purity for the galvanizing process. However, while the revolving scratch-brushes impart to the objects a certain lustre, they acquire by the sand blast a dead lustre and, hence, the blast is also frequently used for the purpose of deadening lustrous surfaces to their entire extent, or of producing contrasts; for instance, dead designs upon a lustrous ground, or *vice versa*.

Fig. 7 shows such a sand blast. The compressed air, whose pressure must be at least equal to an 18½-inch column of water, passes through the blast-pipe *A* into a nozzle running horizontally through the machine, and carries away from there a jet of sand which falls into the outflowing blast, and is hurled upon the objects placed under the nozzle. The objects rest upon sheet-iron plates or in boxes of sheet-iron, which, moving at a slow rate, pass under the nozzle; the motion is effected by the shafts *B B* with the use of rubber belts. To prevent dust the machine is provided with a wooden or sheet-iron casing, a few windows allowing a view of the interior. The sand used in blasting collects in a box and is returned to the sand-reservoir by an elevator.

The jet of sand acts not only upon the upper side of the objects, which it strikes first, but also almost as energetically upon the lower, so that, as a rule, the cleansing process is completed by one operation. Articles of a specially unfavorable shape must be passed twice or three times under the nozzle.

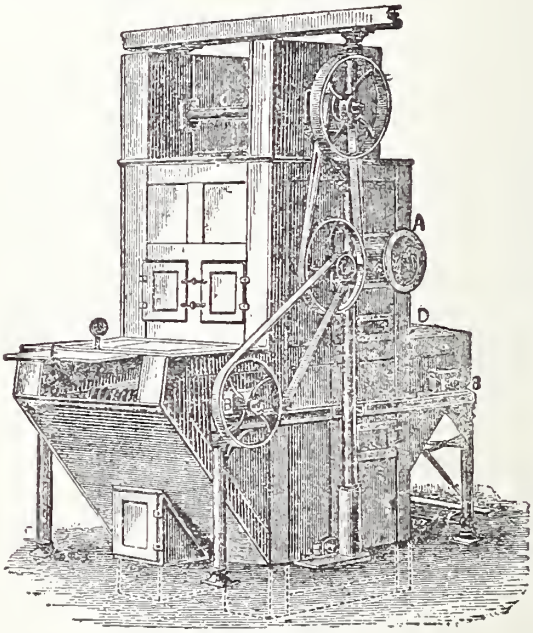


Fig. 7.

Cleansing of Metals by Means of Acids with the Use of a Galvanic Current.—When metallic, especially iron, objects are cleansed and made bright by pickling in an acid, the latter, as a rule, dissolves besides the oxide more or less metal, whereby the surface of the article loses much of its smoothness. To avoid this, the articles to be cleansed are made, while being immersed in the acid mixture, the negative pole of a galvanic apparatus, whereby the metal is almost completely protected. For this purpose a square vessel is used, in the centre of which stand two narrow, porous cells. Each

of these cells contains a number of zinc plates fastened to an iron rod above the cell. In the vessel, on the side of each cell, is a movable bottom provided with holes, upon the upper surface of which is secured an iron bar bent to and fro. This bar is connected by a wire to the rod, to which are suspended the zinc plates of the corresponding cell. For use, the vessel and the cells are filled as full as possible with a fluid consisting of 1 lb. of common salt, 5 lbs. of water, and 26 ozs. of sulphuric or hydrochloric acid. The articles to be cleansed are placed upon the above-mentioned bottoms, whereby they come in contact with the iron bars, and become the negative pole of a simple galvanic apparatus. The cleansing action of the fluid is, if necessary, assisted by heating by means of a steam-pipe placed at the bottom of the vessel.

Scouring and Polishing of Knitting Needles.—For this purpose Kraiten & Schneeloch, of Altena, Westphalia, use a four-cornered box, the length of the knitting needles. The long sides of this box, from about ⅓ their height, run obliquely, with an inclination of 40° towards the interior. On the oblique sides inside of the box move up and down two flat wedges, which above are connected by joints to vertical rods. On top these rods run in guides, and are moved up and down by a crank with connecting rod. Between the two flat wedges the box is filled with about 55 lbs. of knitting needles, a few handfuls of comminuted pebbles, and about 1 quart of oil. The oblique sides force the wedges in passing down to move towards the interior, whereby the knitting needles and pebbles are rubbed together, scouring the former bright. To prevent some of the knitting needles slipping between the wedges and the walls of the box, springs are placed on the stationary guides, which press the wedges against the oblique sides.

To Scour and Polish Needles.—Needles of equal length, but of varying thickness, are placed parallel and in 7 or 8 rows lengthwise upon close, coarse linen, and covered alternately with thin layers of fine quartz sand or emery powder. Rape-seed oil is then poured over the mass, and the whole rolled together in the form of a sausage. These rolls are about 17¾ to 23½ inches long, 3 to 5 inches thick, and contain from 150,000 to 500,000 needles. They

are tied together on the ends, and sometimes wrapped around with a stout cord; 12 to 40 of them are then placed one after the other in the scouring mill. The latter consists essentially of a lower and upper wooden plate, one of which is fluted and can be moved to and fro. When the lower plate is stationary, the whole resembles an ordinary mangle, and it acts also in a similar manner, the rolls containing the needles being set in a rolling motion by the moving to and fro of the fluted plate. By these means the needles rub against each other, and are scoured and polished in the sharp sand.

To Cleanse Guns with Petroleum.—Cleansing a weapon with fats and oils does not entirely protect it from rust; the so-called drying oils get gummy and resinous, while the non-drying oils become rancid, and by exposure to the air acids are formed, and these attack the iron. For these reasons petroleum is to be preferred for this purpose. Petroleum is as great an enemy to water as are the fatty oils, and hence it keeps away the water from a gun-barrel covered with it. It is very essential, however, that the petroleum employed be perfectly pure, for impure oil, such as is often met with in commerce, attacks the metal. Care must also be had not to allow it to come in contact with the polished stock. When about to clean a gun, some tow is wrapped around the ramrod and enough petroleum poured upon it to thoroughly moisten it; it is then pushed in a rotary manner through the barrel and back a dozen times, and the tow taken out and unrolled, and the upper and lower ends of the barrel rubbed with the clean part, after which it is thrown away. This removes the coarser portion of the dirt. A round brush of stiff bristles, and fitting the barrel, is now screwed to the ramrod, then moistened thoroughly with petroleum and twisted into the barrel, running it back and forth at least a dozen times, thus loosening the dirt that is more firmly attached. The first operation is now repeated, except that the tow on the ramrod is left dry, and the rubbing with this must be continued in all directions as long as it comes out soiled. The use of wire-brushes is objectionable for cleaning guns, as the numerous steel points cut

into the tube. Only soft tow, hemp, woollen rags, or the like, should be used, as the petroleum dissolves the dirt sufficiently.

Cleansing of Coins, Medals, and Articles of Silver.—Rössler recommends for this purpose a moderately concentrated solution of potassium cyanide, kept ready for use in a bottle. In cleansing medals and smaller objects place three tumblers alongside each other, two of them filled with water and one with solution of potassium cyanide. Now grasp the objects separately with brass tweezers, and dip them in the potassium cyanide solution; the brownish or dirty yellow coating disappearing at once. Then rinse the objects quickly in the second and third tumblers, and finally dry them with a linen cloth. Larger articles—for instance, spoons, tankards, candlesticks, etc.—are treated by moistening the yellow places with a small brush or tuft of cotton saturated with solution of potassium cyanide, washing and drying. The process is used in the same manner for gilded articles.

To Cleanse Golden-bronze.—Bronze which has become dirty by oil, fat, tallow, or other greasy body, is boiled in an infusion of ashes, and cleansed with a soft brush dipped in a fluid of equal parts of water, nitric acid, and alum. Each piece is then dried with a rag, and slightly heated. To cleanse clock pendulums, and free them from the substance called by the gilders "mercury-dust," heat them moderately, touch the stain with a brush dipped in nitric acid, rub with a linen rag, and again heat moderately.

To Cleanse Bronze Fixtures.—Boil the articles in ordinary soap-boilers' lye, rinse in water, and roll in bran or sawdust. If the bronze is pressed, the lye must be mixed with common salt and the article thoroughly brushed, but no water must touch the back.

To Cleanse Silvered Dial-plates.—Silvered dial-plates of clocks frequently lose their lustre by the effect of air and smoke or sulphurous emanations. To cleanse them make pulverized purified tartar into a paste with water. Take some of the paste on a brush of bristles and rub the dial-plate, turning it constantly until the silvering has acquired its original whiteness and lustre. Then wash

the dial-plate with clean water and dry by gently patting with cloth, and finally expose it for a few minutes to a moderate heat.

To Cleanse Chandeliers and Gas-fixtures.—The chandeliers or fixtures, whether gilded or not, are taken apart and the separate parts boiled for a few minutes in a sharp lye and then cleansed with a soft brush. Next draw them through a strong solution of potassium cyanide, then wash them in a large boiler with hot water, dry them in clean saw-dust and finally polish them with chamois leather. If necessary, lacquer the parts after putting them together.

To Clean Small Screws.—Screws that are too small for separate treatment may be cleaned from rust as follows: Take a pound of screws and place them in a small box—a cigar-box will do; put a small quantity of oil on them and shake for a minute. Then put a piece of cotton-waste in the box and repeat shaking for a minute; finally put a handful of saw-dust in the box and shake for another minute or so and remove the saw-dust by sifting it from the screws in a fine sieve.

To Free Iron from Ingrained Rust.—A thorough cleansing of the iron may be easily effected by immersing the article in a nearly saturated solution of chloride of tin. The duration of the immersion will depend upon the thicker or thinner film of rust; in most cases, however, 12 to 24 hours will suffice. The solution of chloride of tin must not contain too great an excess of acid, otherwise it will attack the iron itself. After the articles have been removed from the bath they should first be washed in water and then with ammonia and be dried as quickly as possible. Articles which have been treated in this manner assume the appearance of dead silver, but their normal appearance may be restored by simple polishing.

To Remove Rust from Polished Steel Articles.—Soak the rusty places for a few days with oil and then scour with emery or tripoli and oil, using a stick of hard wood. Wipe off the oil and all other impurities, rub the stains once more with emery and wine vinegar and finally polish with fine bloodstone and leather.

To Extract Rust from Steel.—Immerse the article to be cleaned

for a few minutes, until all dirt and rust is taken off, in a strong solution of cyanide of potassium, say about ½ oz., in a wineglassful of water; then take it out and clean it with a tooth-brush dipped into a composition of cyanide of potassium, castile soap, whiting and water made into a paste of about the consistency of cream.

To Remove Rust from Nickel-plated Articles.—Grease the rust stains and after a few days rub thoroughly with a cloth moistened with ammonia. The ammonia dissolves the rust without injury to the plating. Should this process be not entirely successful, touch the stains with dilute hydrochloric acid and rub vigorously. Then wash the articles and when dry polish with tripoli or a similar polishing material.

To Freshen up Nickel Watch-movements.—Nickel watch-movements which have become yellow or stained by reason of change of temperature or other influences may be freshened up as follows: To 50 parts of rectified alcohol add 1 part of sulphuric acid. Place the parts to be freshened in this fluid for 10 to 15 seconds, immersing, however, only a few at a time, so as to be able to take them out at the proper time, since a longer immersion would be injurious. When taken from the fluid rinse the parts in clean water and then place them for a short time in rectified alcohol; finally dry them in saw-dust or with soft linen. Nickel movements thus cleaned have almost the appearance of being new, their smoothness being not in the slightest degree injured, as would be the case if the leather-file or brush were used.

Grinding.—The object of grinding metallic surfaces is the same as that of filing and consists in the removal from the surface of very fine particles by the rough grains of the grinding agents. Metals which are to be ground show, as a rule, a very rough surface, it not being possible to obtain another one in casting, forging, hammering, etc. The object of grinding is to give shape to the article or beautify its surface, and the principal condition for executing the grinding process is that the grinding material should under all circumstances be harder than the article to be ground, it being of no consequence whether it is used in a solid form (stones or wheels)

or as a powder. The choice of the grinding material depends entirely on the nature and condition of the article to be ground. Grindstones, for instance, attack hardened steel articles much better than even the best files. The health of the workman being much affected by dry-grinding, it is now chiefly used only for such articles which, for instance, like needles, cannot be conveniently dried separately, but nevertheless suffer much from rust. The fine particles of iron and stone which become detached are best removed by a small, rapidly-running ventilator. In wet-grinding the lower half of the stone runs either in water or is kept wet from above by a gutter; it has the advantage of not wearing out the stone so quickly, of producing finer and more uniform grinding scratches upon the articles and heating them less, which is of special importance in grinding hardened steel. Small grindstones are generally driven by hand, but larger ones by power; special contrivances for securing the article to be ground are also frequently used. In grinding with pulverulent substances the article to be ground remains either stationary or is made to revolve, the grinding agent being pressed against it by the hand or a special contrivance. Generally speaking, it is the same whether the grinding material is moved over the article or the latter over the former, but mostly the article to be ground is held firmly or moved very slowly, while the grinding agent, for instance the grindstone, wheels coated with grinding powder and similar contrivances, revolve very rapidly. Grinding may also be effected by the sand-blast; this process is now much used for cleansing castings, etc.

Rules for the Use of Emery Wheels.—In using emery wheels the following rules are to be observed: 1. To make the most of the use of emery wheels, a strongly built grinding machine upon a solid foundation is the principal condition. 2. The wheel must not be forced or wedged upon the grinding shaft, but must easily fit upon it. For this purpose it is recommended to have the diameter of the wheel-base at least 0.039 inch larger than the diameter of the axis. 3. Place between the iron flanges, which should be about one-third the diameter of the wheel, and the sides of the wheel a disk of

pasteboard or rubber about 0.079 inch thick. 4. The loose flange should not be screwed up tighter than can be done with a wrench with one hand. With thin wheels, especially those for sharpening saws, the nut must be very moderately tightened, and it is best to fix it with a jam-nut. 5. It is advisable in grinding to press whenever possible with the entire hand, since in free-hand grinding even the hardest wheel breaks from the unequal pressure. Unskilled grinders should whenever possible use an adjustable table. 6. The emery wheel is to be protected from every shock, and the maximum number of revolutions must not be exceeded. 7. When a wheel has lost its round shape it should be at once turned by means of a diamond or other suitable tool, as otherwise the efficacy of the wheel is not completely utilized, and the irregular running may cause it to burst. In turning the wheel by means of a diamond, it must be revolved by hand or placed in a lathe.

Emery Wire is a thick or thin wire which is made *sharp* by oiling and then scattering emery over it; it is used either in a form similar to a drill-bow or in the same manner as an emery belt running over pulleys. The wire may also be made sharp by allowing it to run first through a vessel filled with oil and then through one filled with emery powder, by which means there is always fresh emery for grinding.

Emery Sticks are file-like instruments used for working the various metals, as well as other substances, and which in certain cases may replace steel files. They are either round, pointed on one end, or uniformly flat or angular, and consist either through and through of a composition similar to that used for emery wheels, or they are of wood, coated with a thin layer of the above-mentioned composition, or they consist, finally, of emery paper pasted on wood. The manufacture of the first kind is similar to that of emery wheels. For making the second kind, the wood may be coated with a solution of shellac in alcohol, and the emery applied before the shellac is entirely dry; the whole is then dried thoroughly. This coating with shellac and emery has to be several times repeated, until the layer is of sufficient thickness. Care must be had to allow each application of shellac solution and emery to

become thoroughly dry before applying the next, as otherwise the mass remains soft, and readily rubs off. To make the third kind of emery stick, the wood to be used must be very dry and smoothly planed. Coat it first a few times with thin glue solution, and then rub it smooth with glass paper; cut the emery paper into suitable pieces, and, after coating the back with boiling glue, stick it on the prepared wood, being careful to have it perfectly smooth.

To Cleanse Emery which has been Used.—Formerly emery which had been used was considered useless waste, though sometimes attempts were made to make it again available by glowing it, in order to destroy the admixed oil. But other impurities were not removed by this treatment, while, on the other hand, the emery lost its hardness. The oil and other impurities can, however, be removed from the emery without injuring its hardness, as follows: Boil the emery with a sufficient quantity of caustic soda solution of specific gravity 1.015, in order to extract and saponify the oil and fat; this is effected in a cast-iron boiler, and by keeping the emery as much as possible suspended in the fluid by means of a stirring apparatus. After the saponification of the oil, the fluid is drawn off into another vessel; it may then be mixed with acid to separate the fatty acids formed, which, after washing, can be used for various purposes. To the emery remaining in the boiler, water is added, and the stirring apparatus again set in motion to wash out the admixed impurities. The emery is finally dried and, if it does not contain too much iron, is again available. If, however, it contains a large quantity of iron, it is, after drying, allowed to slide down an inclined plane along which electro-magnets are placed, which retain the iron particles. The emery may, however, also be treated with hydrochloric, sulphuric, nitric acids, etc., to dissolve the iron. The emery freed from iron is washed and dried, and, if it should contain much sand, freed from it by winnowing.

Pickling or Dipping of Metallic Objects.—Metallic objects are rendered bright by removing the oxides with an acid. For *cast-iron or wrought-iron articles* mix 1 part of sulphuric or hydrochloric acid with 10 parts of water, add some tar, and immerse the objects in the mixture until the scales are removed from the surface, after

which they are rinsed off in clean water and dried. The purpose of pickling *copper*, *brass*, *tombac*, and *bronze* is to produce a lustrous surface. Finished brass sheets, after passing through the rolls, have a black color, which is partially due to the formation of cupric oxide on the surface, and, partially, to sulphur combinations formed by heating with coal in annealing. In order to impart to the brass its characteristic beautiful yellow color it is subjected to pickling. The operation commences by placing the sheets in a fluid consisting of 10 parts of water and 1 of sulphuric acid. The layer of oxide quickly dissolves, and the sheets show the pure, yellow brass color; they are then washed and dried. In most cases the sheets are subjected to a second treatment with acids, in order to impart to them a beautiful color; hence the treatment with sulphuric acid is generally termed preparatory pickling. As the actual pickle, either nitric acid by itself is used or a mixture of 2 parts of nitric acid and 1 of sulphuric acid. Pickles containing nitric acid possess the property of dissolving zinc from the brass more quickly than copper, the surface of the sheet acquiring in consequence of it a warmer tone, shading more or less into reddish. By exercising great care, dilute nitric acid by itself may be used as a pickle, but the sheets must be immediately washed, since, if only the slightest trace of the acid remains, they acquire after some time a greenish color, due to the formation of a basic cupric nitrate.

It has been observed that nitric acid containing a certain quantity of nitrous acid yields especially beautiful tones of color. To obtain them a small quantity of organic substance is added to the nitric acid or to the mixture of nitric and sulphuric acids. The most curious substances are used for the purpose, snuff, for instance, being highly recommended as especially efficacious in producing beautiful colors. The use of such substances is, however, entirely superfluous, there being a number of cheaper organic substances which, when brought together with concentrated nitric acid, evolve nitrous acid. The cheapest of these materials is dry saw-dust, the nitric acid acquiring a short time after its introduction an orange-yellow color, which is due to the products of decomposition of the

nitric acid, prominent among which is nitrous acid. After taking the sheets from the pickle they are washed, best in running water, in order to remove the last traces of acid. By quick pickling the articles are obtained bright by the removal of the layer of oxide from the smooth surface of the metal. But sometimes a dull lustreless surface is to be imparted to the brass, which is effected by treating the articles with a boiling pickling fluid composed also of nitric and sulphuric acids. In many factories this pickle is prepared by dissolving 1 part of zinc in 3 of nitric acid and mixing the solution with 8 parts each of nitric and sulphuric acids. The solution is heated in a porcelain dish, and the articles to be pickled dipped in it 30 to 40 seconds. In dipping brass articles large masses of red-brown vapors, originating from the products of decomposition of the nitric acid, are evolved, which strongly attack the lungs. The operation should, therefore, be executed under a well-drawing chimney or, still better, in an open space.

The pickled articles have a gray color, and in order to bring out the pure yellow color are immersed for a few seconds in pure nitric acid. They are then drawn through a weak solution of soda or potash and finally washed. The bright metal losing its beautiful color on exposure to the air in consequence of oxidation, the articles after drying must be coated with a good varnish.

The English Process of Pickling Brass is as follows: The articles to be pickled are heated in muffles at a dark red heat and then dipped in dilute sulphuric acid for the production of a clean metallic surface. After heating and dipping, the articles are thrown into a trough filled with weak and impure nitric acid. The trough is of wood, lined with lead plates and, for filling it, nitric acid previously employed for stronger baths is used. When the articles are pure and of a uniform color they are removed from the bath, rinsed in water and dried in saw-dust. They are then deadened. This is effected by bringing them into a bath of nitric acid diluted with about ⅓ water. The immersed articles become coated with a milky scum, which after 1 or 2 minutes disappears. When thoroughly uniform, which is absolutely necessary, the articles are dipped in strong nitric acid and then instantly immersed in various

baths of water to remove all traces of acid. If the article has depressions which might retain acid it is necessary to dip it quickly into warm potash solution. The washed articles are then allowed to lie in clean water to which some crude pulverized tartar has been added. By this treatment they acquire the beautiful dead color so highly valued in commerce. If the articles are to be pickled so as to show lustre they are immediately placed, after cleaning, in strong nitric acid, and if the highest degree of lustre is desired, the entire surface is thoroughly scratch-brushed. Polishing is effected with finely polished steel tools; the articles to be polished are brushed over with ox-gall, and during polishing are from time to time dipped in water containing tartar. Finally they are dried in sanders wood shavings in an iron pan over a heated hearth. They are lacquered with cold shellac solution, which may be colored by an addition of dragon's blood, alkanet, etc.

The Method Usually Pursued in the United States for Cleaning Brass Parts is as follows: Prepare a mixture of 1 part of ordinary nitric acid and 1 part of sulphuric acid in an earthen vessel and have at the same time in readiness a bucket of fresh water and a box of saw-dust. The brass parts are first dipped quickly into the acid, then into the water and finally dried in the saw-dust, by which the brass acquires an excellent lustrous color. Dirty parts are first washed in a warm, strong solution of potash and soda.

Articles of *German silver* are pickled by first immersing them in a mixture of 1 part of nitric acid and 12 of water, then quickly in a mixture of equal parts of nitric acid and sulphuric acid, next rinsing in water and finally drying in pine saw-dust. The greatest care must, of course, be used in pickling, it being especially necessary to see that the acid used is not too strong and that the articles are not allowed to remain too long in the bath, as in both cases great loss is incurred by some of the metal being dissolved. To prevent rusting of the articles repeated washing with clean water and careful drying are also absolutely necessary.

To Pickle Zinc.—Zinc is generally mechanically pickled by scouring with sand and powdered pumice. The bath used for brass is also very effectual. To larger articles which cannot well be

dipped apply a solution of potassium-ammonium tartrate thickened with sufficient clay to form a fluid paste. After a few hours rub the article with a brush dipped occasionally into fine sand moistened with the pickle.

To Give a Brilliant Appearance to Tombac, Brass and Copper, Kaselowsky, of Stuttgart, uses the following process: The articles are first immersed in nitric acid and then quickly washed with much water. They are then dipped, with constant moving to and fro, for one or two seconds in a mixture, prepared at least the evening before, of nitric acid, 70½ ozs.; sulphuric acid, 53 ozs.; hydrochloric acid, 2.82 ozs.; alum, 5.29 ozs.; sal-ammoniac, 3.17 ozs.; and lampblack, 3½ ozs. When taken from this bath the articles must be quickly washed in an abundance of water. The bath is to be prepared as follows: First pour the nitric acid into the vessel, then add the finely pulverized salts, next the hydrochloric acid and, in the course of 1 to 2 hours, gradually, the sulphuric acid. In mixing the acids considerable heat is developed and injurious fumes attacking the respiratory organs are evolved. It is, therefore, advisable to effect the mixture in the open air or under a well-drawing chimney and to use a large vessel, as otherwise, when adding the sulphuric acid, the fluid might run over. This acid mixture has the advantage that it can be used for a long time, it only being necessary to add some sulphuric acid and later on some nitric acid and sal-ammoniac. The objects are but little attacked by the acid mixture, and it is, therefore, especially adapted for printed metal wares and lamp fixtures, to which it imparts a gold-like appearance. Copper, especially galvano-plastic articles, acquire a much brighter and more lustrous appearance by it.

To Polish Metals.—All polishing of metals is begun, in the first instance, by rubbing down the surface by some hard substance that will produce a number of scratches in all directions, the level of which is nearly the same and which obliterate the marks of the file, scraper or turning tool that has been first employed. For this purpose coarse emery is used, or pumice and water, or sand and water applied upon a piece of soft wood, or of felt, skin or similar material. When the first coarse marks have thus been removed,

next proceed to remove the marks left by the first polishing material by finely-powdered pumice stone ground up with olive oil, or by finer emery and oil. In some cases certain polishing stones are employed, for instance, a kind of hard slate used with water. To proceed with the polishing still finer powders are used, such as tripoli and rotten stone. Putty of tin and crocus martis are also used for higher degrees of polish. But the whole process consists merely in removing coarse scratches by substituting those which are finer and finer until they are no longer visible to the naked eye; and even long after that, if the surface is examined by a microscope, it will be seen that what appeared without any scratches is covered all over with an infinity of them, but so minute that they require a high magnifier to be discovered. It is evident that great care must be taken to have the last polishing material uniformly fine, for a single grain or two of any coarse substance mixed with it will produce visible scratches instead of a perfectly polished surface.

Polishing by Means of Wheels.—To give metallic articles the highest degree of lustre, bodies are used which, though they attack the articles very delicately, possess sufficient hardness to remove the scratches and roughness produced by grinding with emery, pumice, etc. These agents are called "polishing agents" or, as they are always used in a pulverulent form, "polishing powders," the most important of them being lime, ferric oxide, tripoli, tin-putty, chalk and graphite.

Lime is used in a burned, unslaked state. It should be free from all admixtures, and especially from carbonic acid and water. An excellent variety is the so-called "Vienna lime." It is prepared from a variety of dolomite which is first burned, then slaked and finally glowed for a few hours. This polishing agent consists of lime and magnesia, and should be kept in well-closed cans, as otherwise it absorbs carbonic acid and moisture from the air and becomes useless. In using Vienna lime the articles to be polished are brushed over either with spirits of wine or oil.

Ferric Oxide is used in its natural state, and is also prepared artificially. The natural ferric oxide, such as hematite, specular and

red iron ores, should be ground fine and elutriated. The polishing agent known as *caput mortuum*, *crocus*, *colcothar*, *jewellers' red or rouge*, obtained by heating ferrous or ferric sulphate in the preparation of fuming sulphuric acid, is also ferric oxide. Both these oxides are very useful polishing agents. For polishing fine articles of steel, gold, gilt, bronze, etc., the jewellers' red is prepared artificially. For this purpose mix pulverized green vitriol with pulverized saltpetre and common salt, stir the mixture with water to a thin paste and boil down the mass in an iron crucible to dryness. The mixture thus obtained is heated in a Hessian crucible at a red heat until it becomes quiet and homogeneous; it is then poured out, and when cool, powdered, boiled with water and washed. It is advisable to somewhat elutriate the powder thus obtained to eliminate grains of sand which may have reached it from the crucible. The powder is finally collected upon a cloth and dried. For 50 parts of crystallized green vitriol 25 parts of pure nitrate of soda, 13 of common salt and 18 of sodium sulphate may be used. A larger addition of saltpetre gives a preparation of a redder color, and an increase of potassium sulphate and a higher temperature one of a more violet color. An increase of common salt produces a browner color, and the jeweller's red is obtained in lustrous lamina; the violet powder is harder than the red. The former (steel rouge) is, therefore, chiefly used for steel, and the latter (gold rouge) for gold and silver.

According to another method, 1 part of soda is dissolved in 4 of water and the solution heated to boiling. Add gradually to the boiling fluid somewhat more than ½ part of green vitriol and continue boiling for some time. When cold a greenish-white mass of ferrous carbonate is found on the bottom of the vessel. Pour off the supernatant fluid, wash the precipitate with much water, then dry it and finally convert it by slight glowing in a clay crucible into red ferric oxide. In using this jewellers' rouge the articles are generally moistened with spirits, though sometimes simply with water.

Tripoli is generally a gray-white or yellow powder of slight hardness, and consists almost wholly of the cast shells of microscopic

organisms. It serves chiefly for polishing soft metals, and is used first with oil and lastly dry.

Tin-putty is artificially prepared by glowing oxalate of tin, which is obtained by decomposing tin-salt with oxalic acid.

Chalk is only used in the form of whiting.

To prevent scattering, the polishing agents are generally mixed with a fluid, water, spirit of wine or oil being used for the purpose. With these fluids the polishing agents are made into a paste and a thin layer of it applied to the polishing tool. For the latter a piece of leather or cloth frequently suffices. It is provided with the polishing agent, pressed by the hand upon the article to be polished and moved to and fro upon it. Smooth articles which can be secured in the lathe are polished by pressing the tool provided with the polishing agent against the revolving article. In this case the flexible pieces of leather or cloth can be replaced by sticks of wood covered with leather or cloth. These tools are called "polishing files." By joining two of them together by a hinge-joint the "polishing stock" is formed, which is used for polishing smooth bodies in the lathe.

Since in polishing, as well as in grinding, it is absolutely necessary that either the work or the tool move with great velocity, disk-like tools are generally used, which are secured either in a lathe or a lathe-like machine, which allows of a still more rapid revolution of the disks than the lathe. These disks are known as buff-wheels, one variety of them consisting of a wooden disk covered with walrus leather.

The last or dead grinding is also executed with such polishing disks. For this purpose very finely elutriated emery is uniformly applied to the leather of the polishing wheel. When dry a second and third application of emery may, if necessary, be made. This disk is called "roughing wheel;" when somewhat worn it is termed "medium wheel," and when almost completely denuded of grinding agent "fine wheel." In grinding with these wheels, oil is used. When the grinding agent is used up the remainder is soaked with warm water and scraped off with a knife to prepare the disk for a fresh application. In consequence of the rapid

rotation of the disk the leather and the layer of emery become brittle and full of fissures. To remove this defect a piece of tallow is held against the revolving disk, and it is then smoothed by pressing a smooth stone against it. For polishing, the polishing agent mixed with oil is applied to the clean leather of the disk.

Another kind of buffing wheel is made by solidly pressing old or new woollen rags between two iron disks provided with holes and pins. The wheels are secured to the spindle of the polishing machine and first made round, which is readily effected by holding the sharp edge of a scythe against the revolving cloth disk. In using the cloth-wheel Vienna lime mixed with oil is first employed and finally dry Vienna lime.

If a large number of small articles, such as buckles, steel beads, metal buttons, steel watch chains, ferules, etc., are to be polished at one time, a tumbling drum or box is used. In its simplest form the apparatus consists of a barrel of suitable size, through the head and bottom of which passes a square axle of hard wood. This axle rests with a pivot of round iron in a suitable frame, and is provided either with a crank or a pulley.

The manipulation of the apparatus varies according to the condition of the articles to be polished. Generally scales and other traces of previous working have to be removed. For this purpose the drum is filled one-quarter full with river sand, and after moistening it with an equal volume of dilute sulphuric acid, as many of the articles to be polished are thrown upon the moist layer of sand that somewhat more than a quarter of the barrel-space remains empty. The aperture for filling is then closed and the drum revolved, the contents being from time to time examined to see whether they are sufficiently scoured. To accelerate the scouring action of the sand it is advisable to provide the drum inside with a few rounded-off wooden pieces, so that the articles placed in it strike each other and are thoroughly shaken up, or the drum itself may be of a hexagonal shape.

After tumbling with sand for 1 to 2 hours, the articles are brought into a drum partially filled with leather-waste, charcoal, emery and oil. When actually ground in this drum they are polished or made

lustrous in a third drum partially filled with Vienna lime to which, for cheapness sake, pulverized charcoal and coarse beech saw-dust may be added.

A very practical form of tumbling drum, in which a change of position of the contents must constantly take place, is shown in Fig. 8. The drum *A*, of wood or iron, is obliquely placed upon the shaft *B*. The objects are introduced into the drum through the door *C*. The drum is revolved by a crank, or by a belt by means of the pulley *D*. All portions of the drum describe thereby

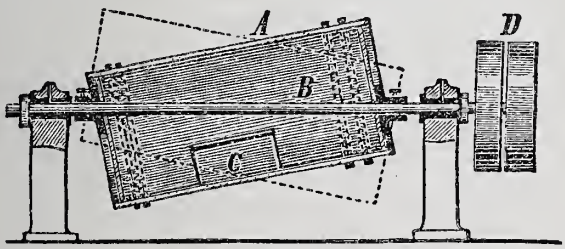


Fig. 8.

ellipses, the walls of the drum being now raised (indicated by the dotted lines) and then lowered, so that the articles in the drum are in constant motion and rub against each other.

According to another method, small articles of iron are first pickled with acid, then washed with boiling water, next scoured bright in a drum with steel powder or powdered cast-iron, and finally polished in a mixture of hard wood saw-dust, elutriated tripoli, and, according to circumstances, jewellers' rouge.

Polishing with the Burnisher or Burnishing-stone.—To burnish an article is to polish it by removing the small roughness upon its surface, and this is performed by a burnisher. This mode of polishing is the most expeditious and gives the greatest lustre to a polished body. It removes the marks left by the emery, tin-putty or other polishing agents, and gives to the burnished articles a black lustre resembling that of looking-glass. The form and construction of the burnisher is extremely variable, according to the respective trades, and it must be adapted to the various kinds of work in the

same art. In general, as this tool is only intended to efface inequalities, whatever substance the burnisher is made of is of little consequence to the article burnished, provided only that it is of a harder substance than that article.

The burnishers used are of two kinds, of steel and of hard stone They are either curved or straight, rounded or pointed, and made so as to suit the projecting parts or the hollows of the piece. Steel burnishers are made of the finest quality of steel, filed into a suitable shape, hardened and ground, and finally polished with Vienna lime or jewellers' rouge. Stone burnishers are made of jasper as well as of agate, but red hematite, known under the name of blood-stone, is most frequently used for the purpose. This raw material is found only in few places, and among several hundred weight of it are frequently found only a few pounds of suitable stones, which generally occur as kernels enclosed in larger pieces. To these pieces an approximate shape is given by skillful splitting. They are then rounded either with the grindstone, or rubbed, so that they present, at the bottom, a very blunt edge, or sometimes a rounded surface. These are polished with emery, like steel burnishers, and are finished by being rubbed upon a leather covered with jewellers' rouge or Vienna lime. Blood-stone is harder than case-hardened steel, the cross-grain of the fibrous pieces especially excelling in great hardness.

Fig. 9 shows the most common forms of burnishing tools. Both must be perfectly free from small fissures and possess the highest polish. The burnisher is mounted in a wooden handle, and firmly fixed by a copper ferule. The operation of burnishing is very simple. Take hold of the tool very near to the stone, and lean very hard with it on those parts which are to be burnished, causing it to glide by a backward and forward movement without taking it off the piece. When it is requisite that the hand should pass over a large surface at once, without losing its point of support on the work-bench, in taking hold of the burnisher be careful to place it just underneath the little finger. By these means the work is done more quickly, and the tool is more solidly fixed in the hand. During the whole process the tool must be continually moistened

with black soap-suds. The water with which it is frequently wetted causes it to glide more easily over the work, prevents it from heating and facilitates its action. The black soap containing more alkali than the common soap, acts with greater strength in cleansing off any greasiness which might still remain on the surface; it also more readily removes the spots which would spoil the beauty of the burnishing. In consequence of the friction the burnisher soon loses its bite and slips over the surface as if it were oily. In order to restore its action it must from time to time be rubbed on the leather. The leather is fixed on a piece of hard wood with shallow

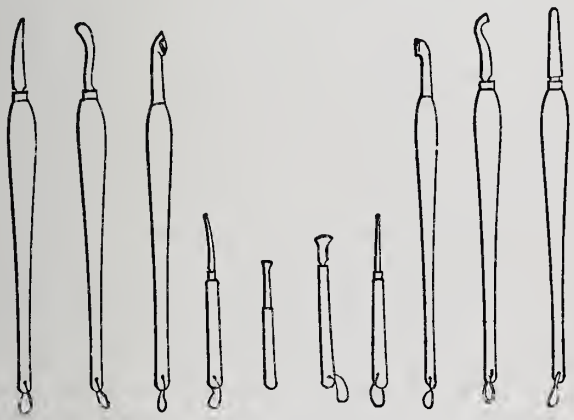


Fig. 9.

furrows along it. There are generally two leathers—one made of sole leather, and the other of buff leather. The first is impregnated with a little oil and jewellers' rouge, and is particularly used for the blood-stone burnishers, the other has only a little tin-putty scattered in the furrows, and is intended exclusively for rubbing steel burnishers, as they are not so hard as the blood-stones. Blood-stone being very hard, the workman uses it whenever he can in preference to the steel burnisher. It is only on small articles and in difficult places that steel burnishers are used, as they by their variety of form are adapted to all kinds of work. In general, the

blood-stone greatly reduces the labor. When the articles, on account of their minuteness, cannot be conveniently held in the hand, they are fixed in a satisfactory frame on the bench, but under all circumstances be very careful to manage the burnisher so as to leave untouched those parts of the work which are intended to remain dull. When in burnishing an article, which is plated or lined with silver, there is any place where the layer of precious metal is removed, restore it by silvering these places. The burnishing being finished remove the soap-suds which still adhere to the surface of the work by rubbing with a piece of old linen cloth. But when there are a great number of small pieces to be finished, to throw them into soap-suds and dry them afterwards in saw-dust is more expeditious. The burnishing of gold-leaf or silver on wood is performed with burnishers made of wolves' or dogs' teeth, or agates mounted in iron or wooden handles. When about to burnish gold applied on other metals, dip the blood-stone burnisher into vinegar; this kind being exclusively used for that purpose. But when burnishing leaf-gold on prepared surfaces of wood, keep the stone, or tooth, perfectly dry. The ordinary engraver's burnisher is a blade of steel, made thin at one end, to fit into a small handle to hold it by. The part in the middle of the blade is rounded on the convex side, and is also a little curved. The rounded part must be well polished and the tool be very hard. This burnisher is used to give the last polish to such parts of copper and steel plates as may have been accidentally scratched, or speckled, where false lines are to be removed, and also to lighten in a small degree such parts as have been too deeply etched or graved. In clock-making, those pieces or parts are burnished which, on account of their size or form, cannot be conveniently polished. The burnishers are of various forms and sizes: they are all made of cast-steel, very hard and well polished; some are formed like sage-leaf files, others like common files—the first are used to burnish screws and pieces of brass, the others are used for flat pieces. The clock-makers have also very small ones of this kind to burnish their pivots, which are called pivot burnishers.

Burnishing Cutlery.—The burnishing of cutlery is executed by

hand or vice burnishers; they are all made of fine steel, hardened and well polished. The first kind have nothing particular in their construction; but vice burnishers are formed and mounted in a very different manner. On a long piece of wood, placed horizontally in the vice, is fixed another piece, as long, but bent in the form of a bow, the concavity of which is turned downwards. These two pieces are united at one of their extremities by a pin and hook, which allows the upper piece to move freely around this point as a centre. The burnisher is fixed in the middle of this bent piece, and it is made more or less projecting by the greater or lesser length which is given to its base. The movable piece of wood, at the extremity opposite to the hook, is furnished with a handle, which serves the workman as a lever. This position allows the burnisher to rest with greater force against the article to be burnished, which is placed on the fixed piece of wood. The burnisher has either the form of the face of a round-headed hammer, well polished to burnish those pieces which are plain or convex, or the form of two cones opposed at their summits, with their bases rounded, to burnish those pieces which are concave or ring-shaped.

To Burnish Silver.—Commence by cleaning off any kind of dirt which the surfaces of the silver articles had contracted whilst being made, as that would entirely spoil the burnishing. For this purpose take pumice-stone powder, and with a brush made very wet in strong soap-suds rub the various parts of the work, even those which are to remain dull, which, nevertheless, receive thus a beautiful white appearance; wipe with an old linen cloth and proceed to the burnishing.

Scratch-brushing.—For brightening articles in relief, steel or stone burnishers can be but seldom employed, scratch-brushes being used in this case. The shape of the scratch-brush varies with the articles to be operated upon. A hand scratch-brush is made of numerous wires of hardened brass selected from a bundle of or coil of large diameter, so that the wires have little tendency when in place to curve. To make a good hand scratch-brush, proceed as follows: Select a coil of brass wire of the proper degree of fineness

(Fig. 10), and bind it tightly with strong twine for about two-thirds of the intended length of the brush—6 or 8 inches—(Fig. 11), Then, with a chisel, cut the bundle of wire close to the cord at one end, and about 2 inches from it at the other end. Then dip the close-cut end into a neutral solution of chloride of zinc, and plunge it into molten tin, which solders all the wires and prevents their separation, and injury to the hand of the operator. The tool thus made may be used as it is, but it is preferable to fix it by means of another string to a thin wooden handle, which projects above the soldered end (Fig. 12). Scratch-brushes are also made by cutting a coil of wire for a length of from 12 to 16 inches, binding it in

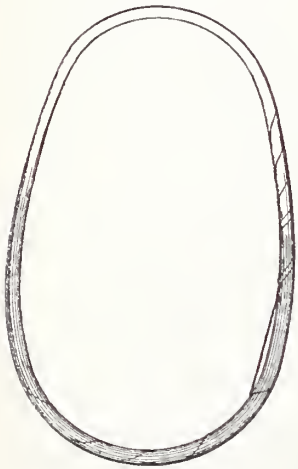


Fig. 10.

Fig. 11.

Fig. 12.

Fig. 13.

the middle, and doubling it so as to unite the two ends (Fig. 13). This process is less economical, and the wires have a tendency to become entangled. Very small scratch-brushes are necessary for reaching sinuosities and depressions in the work, and other parts difficult of access. An old scratch-brush, the wires of which have

been bent in every direction, when fixed to a long handle, is useful for scouring the interior of certain pieces, such as Etruscan vases, coffee-urns, etc. (Fig. 14). The varnishers on metal use for rapid work a kind of brush (Figs. 15 and 16), with long and stiff brass wires. Such brushes are only used for the preparation of articles of considerable size, such as clock dials, hearth furniture, and the like.

Fig. 14.

Fig. 15.

Fig. 16.

Scratch-brushing is seldom done dry; the tool as well as the pieces must be constantly wet with fluids, especially such as produce a foam in brushing, for instance, water and vinegar, or sour wine, or solutions of cream of tartar or alum, when it is desired to brighten a gold deposit which is too dark; but that most generally used is a decoction of licorice-root, of horse-chestnut, of marsh-mallow, of soap-wort, or of the bark of Panama-wood, all of which being slightly mucilaginous, allow of a gentle scouring with the scratch-brush, with the production of an abundant froth. A good adjunct for scratch-brushing is a shallow wooden tub containing the solution employed, with a board laid across it, nearly level with the edges, which, however, project a little above. This board serves as a rest for the pieces.

With small objects and articles of jewelry, the operator holds the scratch-brush as he would a writing-pen, and moves it over the article with a back-and-forward motion imparted by the wrist only, the forearm resting on the edge of the tub. For larger articles, on the contrary, the operator holds his extended fingers close to the lower part of the scratch-brush, so as to give the wires a certain support, and, with raised elbow, strikes the piece repeatedly, at the same time giving the tool a sliding motion. When a hollow is

met with which cannot be scoured longitudinally, a twisting motion is imparted to the tool.

Circular scratch-brushes in which the wires are arranged radially are used for scouring articles that admit of their use, such as table ware and plated wares in general. These circular scratch-brushes

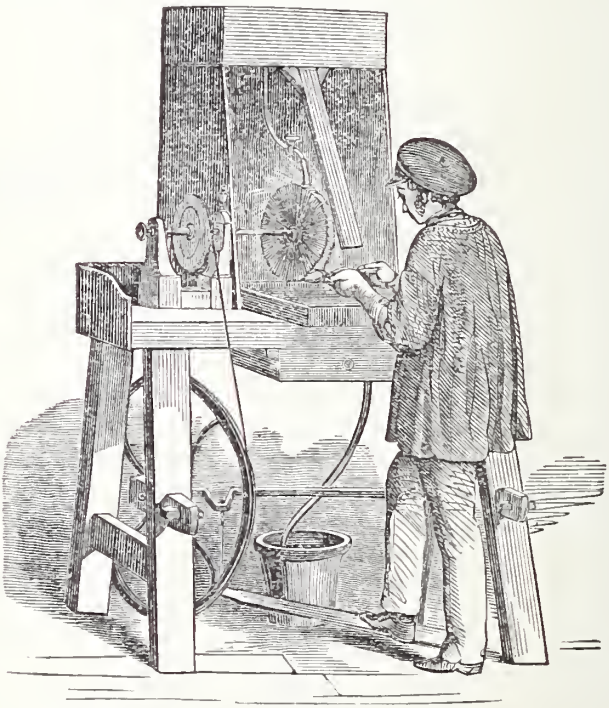


Fig. 17.

are attached to the spindle of a lathe, and the wires consequently all receive a uniform motion in the same direction. The scratch-brush lathe shown in Fig. 17 consists of a circular brush of brass wires, with a metal or wooden case, mounted upon a spindle running in two bearings, and driven either by foot or by steam-power. The wires are from 2 to 3 inches long, and the form of the brush

is shown in Fig. 18. The top of the brush revolves towards the operator, who presents the object to be scratched to the bottom. The brush is surrounded by a wooden cage or screen to prevent splashing. It is open in front, and above it is placed a reservoir of one of the liquids above named, from which a slender jet of the liquid is allowed to dribble upon the top of the brush. In order to protect the operator against the water projected by the rapid motion, there is fixed to the top of the frame a small inclined board, which reaches a little lower than the axis of the brush, without touching it. This board receives the projected liquid and lets it fall into a zinc trough which forms the bottom of the box.

Fig. 18.

Through an outlet provided in one of the angles of the trough a gum tube conveys the waste liquid to a reservoir below.

The above-described hand and lathe scratch-brushes are made of wire of various gauges, from coarse to very fine, according to their intended uses. Scratch-brushes of spun glass, with fibres of extreme fineness and elasticity, are also used for scouring very delicate objects.

When a hand scratch-brush becomes too short the twisted ends are cut off with a cold-chisel, and a new portion of wire is uncovered by removing part of the string wrapping. The best way to remove the twisted-wire ends is by resting the scratch-brush upon a lead block, and cutting them off with a sharp cold-chisel, if possible with one stroke of the hammer. Scratch-brushes must be carefully looked after and their wires kept in good order. When they begin to curl, they are now and then beaten with a mallet of

boxwood upon a small block held between the knees, so as not to produce a dead stroke. Scratch-brushes kept too long in water become hard. If they become greasy, they are cleansed in caustic potash; oxide is removed by acid. Dipping in nitric acid is sometimes resorted to for diminishing the size of the wires and making them smoother. The circular brush is occasionally reversed, in order to change the direction of the wires.

Polishing of the Separate Metals.—Iron and Steel are generally polished after treatment with emery. For this purpose tin putty, Vienna lime or oxide of iron (steel rouge) are generally employed, the polishing material or the article being moistened with water or spirit. Polishing wheels (buff or cloth wheels) are best for the purpose, though buff sticks and wooden sticks as well as woollen rags are also employed.

Copper, Brass, German Silver and Tombac are polished with Vienna lime and oil. If previously pickled the burnisher is mostly used.

Polishing with the burnisher is always executed wet. Gas-fixtures are polished, after pickling, in the spinning lathe with the burnisher, a peculiar fluid (polish) being used, which, according to O. Ronicke, is composed of: orange shellac, dissolved in spirits, 1000 parts by weight; powdered turmeric root, 1000; tartar, 2000; ox-gall, 50; alcohol, 100; and water, 3000. Dip the burnisher in the fluid and polish the article, or wrap a linen rag moistened with the fluid round a piece of wood and hold the rag with the left hand upon the place where the pressure with the burnisher is applied. By drying the article with a linen rag a polish equal to that with Vienna chalk is obtained.

Gold is polished with jewellers' rouge, which is mixed with alcohol and applied to the buff-stick.

Silver is polished with the burnisher or bloodstone, soap water, small beer, etc., being used in connection with it.

Silvered and Plated Ware are also polished with Vienna lime.

Dead Lustre on Articles of Gold and Silver is produced by means of scratch-brushes of finely spun glass threads.

Tin Articles are ground and polished with Vienna lime or whiting,

the first being used with linen rags and the latter with chamois leather. If only places in relief are to be polished a broad, rounded-off burnisher is used and as polishing agent soap water, white of egg, ox-gall diluted with water, decoction of soap root, etc. The articles are finally washed with water containing tartar and dried.

Antimony and Lead Alloys are polished with burnt magnesia upon soft leather or with fine jewellers' rouge.

Zinc is first scraped and finally polished with pulverized wood charcoal or Vienna lime.

The polished articles are generally dried in heated saw-dust and, after drying, freed from adhering saw-dust with a cotton rag or soft leather. Gilded or silvered articles are dipped in hot water, dried with cotton or linen cloths and finally rubbed with soft leather.

Vienna lime produces a light polish upon brass, steel, etc., but iron oxide a dark lustre, the difference in the coloration being very likely due to some of the polishing agent remaining in the pores of the metal.

Polishing Agents.—Old and used metallic objects lose in the course of time their lustre produced by polishing; they become dull and covered with a crust of dust, oxides, sulphur combinations, etc. To cleanse such objects polishing agents acting either mechanically or chemically are used.

To the mechanically acting polishing agents belongs the so-called Paris rouge. It is used for restoring lustre to gold articles by carefully rubbing them with leather dipped in it. Under the name *Parisian polishing powder* a rose-colored powder is brought into commerce. It is especially adapted for polishing silver, but may also be used for articles of steel, copper or gold. It consists of a mixture of 6 parts of carbonate of magnesia and 1 of jewellers' red. For use dip a rag moistened with spirits or water in the powder and after thoroughly rubbing the article dry it with soft leather.

Emery-cloth may be used for scouring, but it gives no lustre, because the polishing agent is sharp-grained and applied to the cloth. More suitable is a polishing agent consisting of fustian saturated with a dilute solution of waterglass. By washing the impregnated

stuff the silicic acid and a portion of the potash remain behind. This polishing cloth is well adapted for cleansing and scouring bright brass.

Another kind of *polishing rags* is obtained by dissolving 4 parts by weight of Castile soap in 20 of water and adding 2 of tripoli to the solution. Strips of linen are then saturated with the solution and allowed to dry. According to another method polishing rags are prepared as follows: Dip flannel rags in a solution of 20 parts of dextrin and 30 of oxalic acid in 20 of logwood decoction, wring them gently and sift over them a mixture of finely pulverized tripoli and pumice stone. The moist rags are piled upon each other, placing a layer of the powder between each two. They are then pressed, taken apart and dried.

Belgian Polishing Powder, which is recommended for polishing articles of silver, consists of a mixture of whiting, 250 parts; elutriated pipe-clay, 117; white lead, 62; white magnesia, 23; and jewellers' red, 23.

For *Cleansing Iron and Steel Objects* finer grades of emery-cloth are very suitable. For *polished* iron and steel articles it is best to use tin-putty and prepared hartshorn triturated with spirits of wine and applied with soft leather.

For *Soft Metals* (*Tin and Britannia Wares*) the dried pistil of shave-grass, which is rich in silica, is very suitable.

For Cleansing Silverware the most simple (chemically acting) polishing agent is sodium hyposulphite. Moisten a rag or brush with a saturated solution of the salt. Still better in its action is a fluid of water, 40 parts; sodium hyposulphite, 4; sal-ammoniac, 2; and caustic ammonia, 1. This fluid may be used cold and it is not necessary to previously free the articles from grease with soda or potash lye.

For Cleansing Silver Ornaments use a boiling hot solution of tartar or wrap them around with zinc wire and boil them in a solution of 1 part of borax in 10 of water. In both cases the articles must be previously cleansed with soda lye.

Polishing Powders for Silver.—I. Mix intimately finely pulverized cream of tartar, 4 parts; flake white, 8; pulverized alum, 2.

Knead the mixture into a stiff paste with strong wine vinegar and dry it in the air. Then pulverize the dry mass, knead it again to a paste with wine vinegar, repeat the process once more after drying and lastly pulverize the mass obtained.

II. Mix intimately pulverized hartshorn, 1 part; chalk, 5; and jewellers' red, 1.

III. Mix intimately by sifting 10 parts of fine whiting, 1 of pulverized soda and ¼ of pulverized citric acid. For use moisten the powder with water so that the soda and citric acid dissolve and act chemically upon the silver.

English Silver Soap.—This polishing agent, by means of which and the use of a brush a nice lustre is imparted to silver articles, is prepared as follows: Dissolve 2 parts of Castile (pure olive oil) soap in 2 parts of soft water. Take the soap-paste formed from the fire, stir into it 6 parts of fine whiting, pour the soap into moulds, and allow it to cool.

Rose-color English Silver Soap.—This is prepared in a similar manner as the foregoing, but instead of mixing the soap-paste with whiting, add 2 parts of finest quality of white tripoli, 3 of pulverized chalk, and 1 of jewellers' red. Before pouring the soap into moulds perfume it with a few drops of oil of lavender, which imparts to it a very fine odor, and renders it more salable than soap without perfume.

Polishing Balls for Silver.—This polishing agent is a powder brought into the form of a ball by means of an agglutinant. It is prepared by intimately mixing 2 parts of yellow tripoli and 5 parts of whiting, kneading the mixture with a solution of 1 part of gum-arabic in 12 of water to a stiff paste, and finally forming the latter with the hands into balls the size of a pigeon egg. These balls are dried upon boards in a moderately warm room, and, when perfectly solid, are packed in tin-foil.

Polishing-paste for Silver.—Perfume 3 parts of vaseline with a few drops of nitrobenzol (essence of mirbane), and stir into it 5 parts of whiting, 1 of burnt hartshorn, and 1 of pulverized cuttle-bone, so that an intimate mixture of the consistency of butter is formed. Put into small tin boxes.

Polishing Powder for Gold-workers.—Mix together 4.3 parts of carbonate of lead (basic white lead), 17.4 of chalk, 1.7 of carbonate of magnesia, 4.3 of alumina, 2.6 of silica, and 1.7 of jewellers' red.

Polishing Powder for Gold Articles.—Dissolve iron filings in hydrochloric acid until the development of gas ceases, and then compound the resulting chloride of iron with liquid ammonia as long as a precipitate is formed. Collect the precipitate upon a filter and dry it, without further washing, at a temperature at which the adhering ammonia does not volatilize. By these means the ferrous oxide originally precipitated is converted into ferric oxide, and the mixture contains about 70 per cent. of ferric oxide and 30 per cent. of ammonia. It forms a very good polishing powder.

Polishing Paste for Brass.—Dissolve 15 parts of oxalic acid in 120 of boiling water, and add 500 parts of pumice powder, 7 of oil of turpentine, 60 of soft soap, and 65 of any kind of fat oil.

To Cleanse Brass Articles which have become so dirty by smoke and heat that they cannot be cleansed with oxalic acid, proceed as follows: Rub them first with potash lye, then immerse them in a mixture of equal parts of nitric and sulphuric acids and water, and after washing and rinsing in water, dry and polish.

To Cleanse Old Brass.—To cleanse old brass, especially small figures, sword-hilts, mountings, etc., immerse them in a mixture of 1 part of nitric acid and ½ part of sulphuric acid. Take them out after a short time, rinse thoroughly in cold water, dry in sawdust, and finally polish with finely pulverized Vienna lime. The articles will appear like new.

Polishing Soaps.—I. Stir into 25 lbs. of liquid cocoanut-oil soap 2 lbs. of tripoli, and 1 lb. each of pulverized alum, tartaric acid, and white-lead.

II. Stir into 25 lbs. of liquid cocoanut-oil soap 5 lbs. of colcothar and 1 lb. of ammonium carbonate.

III. Mix 25 lbs. of liquid cocoanut-oil soap with 4 to 5 lbs. of calcined oxalate of iron.

IV. Stir together in the customary manner 24 lbs. of cocoanut oil

with 12 lbs. of lye of 38 to 40° Bé., and, when the mass is bright, stir into it 3 lbs. of colcothar, mixed with 3 lbs. of water and 1.12 ozs. of spirit of sal-ammoniac.

The polishing soaps are cut into suitable pieces, stamped, and brought into commerce provided with directions for use. These directions are generally to the effect to apply a small quantity of the soap by means of a flannel rag moistened with water to the article to be polished, and rub until the desired lustre is produced.

Krätzer, of Leipzig, gives the following directions for polishing soaps as substitutes for polishing pomades: I. Pulverize as finely as possible 332 parts of white bole or chalk, 332 of tartaric acid, and 265 of infusorial earth. Free the bole or chalk and the infusorial earth from adhering pebbles by sifting. Pour water over the sifted mass in a vessel, stir thoroughly, and after 3 or 4 minutes pour off the bole, etc., which is finely divided in the water, and repeat the operation. The bole, etc., is then allowed to settle, and after carefully decanting off the supernatant water, the sediment is placed upon a filter and completely dried upon a stove. To the ingredients thus prepared add 200 parts of glycerin, 200 of water, and 25 of alcohol. The polishing soap thus prepared is poured into tin boxes or moulds.

II. Mix 5 lbs. of cocoanut oil with 8 lbs. of soda lye of 23° Bé., and boil the mixture until a clear glue-like mass is formed. When the soap is sufficiently solid add 1 lb. of chalk and ½ lb. each of white-lead, tartar, and alum, all previously converted into a fine powder, and pour the mass into small moulds about 10 inches long, and open on top and bottom so that the cold soap can be more readily removed. For convenience sake, commercial cocoanut-oil soap may be used instead of preparing the soap. The process is as follows: Convert 5½ lbs. of cocoanut-oil soap into fine shavings, and melt it with the addition of some water. To the melted soap add then, with constant stirring, 6.34 ozs. of chalk, 3 ozs. of alum, 3 ozs. of tartar, and 3 ozs. of white-lead, all previously finely pulverized. This soap is also poured into tin moulds open on top and bottom, and taken out when cold.

Polishing-water.—An excellent and entirely harmless polishing-

water is obtained by shaking together 8.81 ozs. of whiting, 1 lb. of alcohol, and 1.12 drachms of spirit of sal-ammoniac.

Polishing (*Putz*) *Pomades.*—I. Melt 5 lbs. of lard or yellow vaseline, and stir into the melted mass 1 lb. of fine colcothar.

II. Melt 2 lbs. of palm oil and 2 lbs. of vaseline, and stir into the melted mass 1 lb. of ferric oxide, 14.11 ozs. of tripoli and ¾ oz. of oxalic acid.

III. Heat 4 lbs. of American mineral oil and 1 lb. of lard, and stir into it 5 lbs. of fine colcothar.

The polishing pomades are generally perfumed with nitrobenzole (essence of mirbane), and brought into commerce in small tin boxes provided with directions for use.

Polishing Cartridges (*Putzpatronen*).—Moisten 50 parts of elutriated quartz or infusorial earth and 10 of emery-dust with 100 parts of a 30 per cent. gum tragacanth solution, and bring the whole to a suitable consistency with soap solution (100 parts of soap dissolved in 150 of spirits of wine). The best polishing material is undoubtedly infusorial earth, either by itself or impregnated with oleic acid. Infusorial earth by itself is especially suitable for polishing windows, mirrors, gold and silver ware, copper and brass utensils, particularly when greasy.

Polish for Pressed Articles of Brass.—Substances which are slimy without being actual fats are better adapted for this purpose than soap, and can be more readily removed from the articles. The best polishing agent is equal volumes of water and ox-gall boiled together. When cold the fluid is kept in well-corked bottles, and for use a sufficient quantity is poured into a glass or porcelain vessel. It is applied with a small brush, and the burnisher is also from time to time dipped into it.

Rouge for Polishing Metals.—As the rouge found in the market does not meet the requirements of the workman, at least for every metal, the following simple method is given which allows the workman to prepare for himself just the quality and quantity necessary for his particular work. Heat sulphate of iron (as pure a quality as can be obtained) in an iron vessel over a slow fire, stirring it continually with an iron spatula till it is dry and takes the form of

a pale greenish-yellow powder. This powder, after being crushed in a mortar and sifted, is to be calcined in a new crucible and exposed to the fire of a smelting-stove as long as vapors arise from it. As soon as no more of these can be observed the contents of the crucible may be left to cool, and when cool will appear like the rouge used for polishing. Its color may vary from pale red to brown red, or even to blue and violet, but these variations arise only from the different degrees of heat employed; and it may be observed that the higher the temperature has been during the process the darker the color and the harder the powder—a fact which also explains why the pale-red powder is used only for gold and silver, while the violet is employed for steel. No matter what the color is, it is very important that the rouge be well bruised and washed in water before it is used. For this purpose three clean glasses are taken and one of them is filled with clean water, in which a part of the rouge is mixed by stirring it for some time with a small piece of wood. After allowing about half a minute for the rouge to settle to the bottom of the glass, the remainder of the (red) liquid is decanted into the second glass, but every particle of the deposit must be left in the first one. The same process has to be observed also for the second and third glasses, but with this difference: the powder in the second glass is allowed to settle about 2 minutes, while in the third one it is left for several hours, that is, until the water assumes its natural clearness. The sediment of the first glass is almost valueless, that of the second of medium quality, but that of the third glass is of very good quality and fit to be used with great advantage after it has been slowly dried. In some cases the rouge thus obtained may be mixed with grease, and generally it will be found of great advantage to moisten it with spirits of wine and burn it in a clean iron vessel.

To Polish Steel.—Rub the steel with a piece of emery paper from which you have removed some of the roughness by rubbing it on an old knife.

To Polish Steel Objects.—This process consists in polishing the steel objects by means of a wheel or disk made of 16 parts of tin and 1 of zinc, to the flat side of which jewellers' red moistened

with alcohol is applied. After moderately drying the objects are burnished with an agate.

Lustreless Surface on Steel.—A finely-polished lustreless surface on tempered steel may be procured by either of the following operations: After the steel article has been tempered it should be rubbed on a smooth iron surface with some pulverized oil stone until it is perfectly smooth and even, then laid upon a sheet of white paper and rubbed back and forth until it acquires a fine dead polish. Any screw-holes or depressions in the steel must be cleaned and polished beforehand with a piece of wood and oil stone. This delicate lustreless surface is quite sensitive and should be rinsed with pure soft water only. A more durable polish is obtained by first smoothing the steel surface with an iron polisher and some powdered oil stone, carefully washing and rinsing. Then mix in a small vessel some fresh oil and powdered oil stone, dip into this mixture the end of a piece of elder pith, and polish the steel surface with a gentle pressure, cutting off the end of the pith as it becomes soiled. In conclusion, it should be thoroughly cleaned in soft water, when the article will be found to have a fine white, lustreless polish.

To Polish and Color Copper.—To polish copper parts rub them with rotten stone and oil, next with a flannel rag and finally with leather. A solution of oxalic acid applied to dull brass soon removes the layer of oxide and uncovers the metal. The acid is then washed off with water, and the brass rubbed with soft leather. A mixture of hydrochloric acid with alum triturated with water gives to articles, immersed in this solution for a few seconds, a golden color. An orange-color playing into gold is imparted to polished copper by immersing it for a few seconds in a solution of crystallized acetate of copper. A beautiful violet color is obtained by immersing the metal for a few seconds in a solution of chloride of antimony and then rubbing with a stick wrapped around with cotton. During this operation the copper must be heated to the temperature of the hand. A crystalline appearance is produced by boiling the article in solution of blue vitriol.

To Cleanse Dirty Polishing Leather.—Prepare a weak solution

of soda in warm water, rub some soap into the leather and let it soak two hours; then wash it until clean and finally rinse it in a solution of soda and yellow soap in water to keep it soft. By washing in water alone the leather becomes hard and useless, but the small quantity of soap which remains in the leather and penetrates the finest portions renders it soft as silk. After rinsing wring the leather in a coarse towel and dry it quickly; when dry pull it in all directions and brush well. By these means a softer and better leather will be obtained than most of the leathers found in commerce.

In using a rough leather to go over highly polished surfaces it will be frequently observed that the polish is injured. This is caused by particles of dust and even grains of polishing-red which remain in the leath Such leather should be thoroughly brushed.

X.

DECORATING, ENAMELLING, ENGRAVING, ETCHING.

Bronces Incrustés (*Incrustations*).—By this term are designated ornamentations in silver or gold upon a body of massive copper or bronze. The body is, as a rule, first bronzed, since its natural tone of color is generally subject to change by atmospheric influences and does not present a good contrast. Copper, for instance, is generally bronzed brown-red, the white of the silver contrasting well with it. The ornamentations consist partially of lines and partially of planes, calling to mind niello work. While in the latter the noble metal is mechanically pressed into the places depressed by engraving or roughened with a file, in incrusting, as executed by Christofle, of Paris, the deposition of the metal is effected by galvanic precipitation. The process is as follows: The design which is to be incrusted in silver or gold upon a metal is executed with a pigment of white-lead and glue-water or gum-water. The portion not covered by the design is then coated with a varnish. The article is next placed in dilute nitric acid, whereby the pig-

ment is first dissolved, and, next, the surface etched, which is allowed to progress to a certain depth. Etching being finished the article is washed in abundance of water and immediately brought into a silver or gold bath, in which, by the action of the current, the exposed places are filled up with metal. The varnish is now completely removed with benzine and the entire surface ground smooth. The contours are quite sharp. The surface of the body is then bronzed, which, however, does not change the tone of the silver or gold. An especially beautiful effect is produced by bronzing separate portions of the surface, between the silver ornamentation, black with sulphide of copper. A vessel thus decorated then shows three tones of color, viz.: the design in white and black upon the agreeable brown-red ground of cuprous oxide. The principal requisite for the production of these incrustations is manual skill and much patience; expensive apparatus is not required, every skilled electro-plater being able to execute the work.

According to the patented process of Marie Tessin du Motay, the portions to be provided with incrustations are not only produced by etching but also by stamping and pressing. In the latter case the metals which are to represent the design may be precipitated either before or after pressing. If the precipitation takes place before pressing the relief of the stamps used must correspond to the greater or smaller layer of metal precipitated.

Corvin's Niello.—On account of the laborious work and slight durability of the ornamentation, the decoration of metallic surfaces by inlaying with colored lamina of mother-of-pearl, amber, ivory and tortoise-shell has been seldom executed, though by a combination of the iridescent mother-of-pearl with the various metallic lustres the most splendid articles of art can be produced. After many years of labor Corvin-Wierbitzky has succeeded in producing such works by galvanoplasty, and has patented the following process: He first makes a matrice of metal, whose surface is finely polished. This matrice may be used for the production of numerous duplicates of the same kind of basin or other objects. The incrustations (mother-of-pearl, glass, ivory, amber, etc.) are then shaped by means of a saw, files and other tools to the form cor-

responding to that which they are to occupy in the design. The side of the incrustations which is laid upon the matrice is as a rule smooth. The shaped incrustations, smooth side down, are pasted on to the parts of the model they are to occupy in the design. The latter being in this manner produced, the back of the non-metallic lamina is prepared so as to conduct the galvanic current. By now placing the matrice thus prepared in the galvano-plastic apparatus, the copper precipitates not only upon the metallic matrice, but also upon the back of the inlaid pieces, the latter being firmly enclosed by the precipitated metal. When the deposit of metal has the desired thickness it is detached from the slightly-heated matrice, and incrustations with the right side polished are thus obtained. The lamina are more accurately and evenly laid in than would be possible by the most skilful hand-work. The articles may then be further decorated by engraving, gilding, silvering, etc.

Damaskeening.—Damascus steel is a special kind of carbon steel which is manufactured according to Anossow's process in Slatust in the Ural. The sword blades celebrated for centuries for their good qualities derive their name from Damascus in Asia Minor, but nothing is known about their manufacture. It has been tried, as will be explained later on, to imitate the damask by welding together strips of iron and steel, but, though the designs were quite beautiful, genuine damask was not obtained. The designs of damask consist of a peculiar net-work of light lines standing out from a dark ground, and showing either a moiré striped lengthwise or wavy or net-like or ribbon-like. A good Damascus blade will cut an iron nail without suffering injury. For the production of Damascus steel, according to Anossow's process, iron together with graphite and a flux is melted in a crucible. The cake of steel found after cooling upon the bottom of the crucible shows already a damaskeened surface, and is then carefully worked further in the ordinary manner.

Imitation of Damascus Steel.—Cut 8 sheets of steel 12 inches long, 1 inch wide and $\frac{1}{12}$ inch thick. Now prepare 5 sheets of soft iron and 4 of brittle iron of equal dimensions with the steel sheets. These are then joined together in the following manner:

A sheet of steel is laid upon one of soft iron, upon this one of brittle iron, then one of steel, and so on to the seventh sheet, which should be one of soft iron. The bundle is placed in the fire, and, after moderately heating, welded together. It is then squared and worked smooth under the hammer and brought to a white-heat. One end is then placed in a vise, the other is grasped with a pair of tongs and the mass vigorously twisted into the shape of a screw. It is then smoothed and wrought into a bar ½ to ¾ inch wide and ⅕ to ⅓ inch thick. This is cut into 2 equal parts. A sheet of steel ⅛ inch thick, and as long and as wide as one of the two parts of the prepared bar, is cut and placed between the two parts. The bundle is placed in the fire and then beaten under the hammer to the thickness required for the articles to be manufactured. A pickle consisting of 1½ pints of water, 1 oz. of nitric acid, 1 oz. of sal-ammoniac and 4½ drachms of blue vitriol is now prepared in a copper vessel. Paint the places which are not to be damaskeened with some kind of varnish, and place the articles manufactured from the prepared bar in the bath. When the pickle has taken effect they are removed, rinsed off with cold water and dried.

Damascus Gun-barrels.—The best known varieties of damask are the "rose and Bernard damask." The process of manufacturing the first variety, which is also called "Turkish" damask, is shown in Fig. 19 *A*.

Square rods of the thickness of a lead-pencil are first formed by arranging 26 ribands of iron and mild steel as thick as paper, in alternate layers, welding the whole together and twisting it like a rope by securing one end in a vise and grasping the other with a pair of tongs. Six such twisted rods are then welded together as shown at *A*, Fig. 19, and twisted around an iron tube *h*. These crude barrels are worked, while hot, under the hammer until all parts are uniformly united. When the barrel is finished the tube around which the riband of damask is twisted is bored out. The finished barrel is filed smooth and polished, and then treated with dilute nitric acid, when it exhibits a diversified laminated structure, resembling when properly managed an ostrich feather.

Barnard damask is made by alternately arranging 81 square rods of iron and steel in the manner of a chess-board, *B*, Fig. 19, welding the whole together, twisting it like a rope, and again welding three such ropes for the formation of the riband, which is then twisted around the iron tube. Fig. 19, *C*, shows the design of the damask of a double-barrel gun. In this case the iron and steel bands are placed one upon the other before heating and held together by wire.

To Damaskeen Iron and Steel with Platinum.—Take several thin steel sheets or alternately steel and iron sheets, wrap around each a platinum wire, and after placing one upon the other, firmly tie the whole together with steel wire in such a manner that

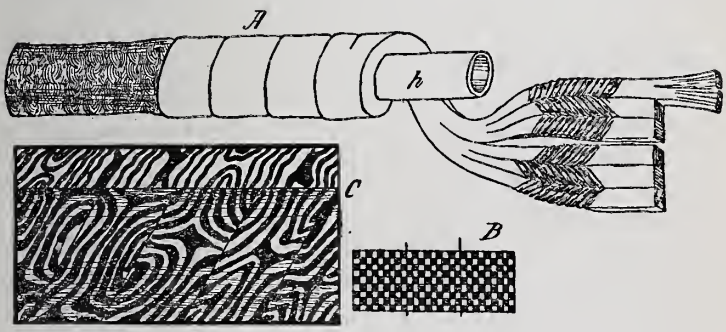


Fig. 19.

the last wrappings touch each other. The whole is then welded together, best with the use of borax. The mass thus obtained can then be worked further as desired. By browning or bluing the finished article the lustrous white platinum damask appears upon a blue or brown ground. Instead of platinum other refractory metals, for instance, nickel, may be used.

Damaskeening with Gold or Silver.—There are two methods of practising this process. By one method the surface of the metal to be damaskeened is roughened with a file; the artist, by skilful manipulation, causes to adhere to the roughened surface threads of gold or silver, which are pressed down and burnished. Broad sur-

faces are produced by working the threads or wires side by side. Heat is applied, but the necessary degree requires great judgment. In the other method the surface to be damaskeened is incised or cut into, the incision being expanded at the bottom. Into this channel gold or silver is introduced and beaten down.

Imitation of Damask.—Prepare a mixture of equal parts of good linseed oil varnish, white resin and wax. Coat with this the iron, which should have been previously cleansed and polished, and draw with a pen the pattern usually used in damaskeening. Make a rim of wax around the pattern, and pour nitric acid mixed with an equal quantity of lemon juice upon the pattern. As soon as the nitric acid assumes a brownish color pour it off, wash the iron thoroughly with water and remove the varnish by melting. If the article is small, round, or has an uneven surface, place it for a few minutes in a mixture of 8 parts of water, 1 of nitric acid, and 1 of lemon juice, and allow it to remain until the fluid assumes a brownish color, when it is taken out and cleansed.

To Produce Damask in Relief upon Gun Barrels.—Carefully close all openings of the barrel with corks and cleanse it from adhering grease. Then place it in a box, pitched inside, and pour over it one quart of water previously mixed with 1 oz. of hydrochloric acid. The barrel remains in this mixture for 3 to 4 hours, when it is taken from the box, washed with water, next rubbed with tow dipped in tripoli and finally thoroughly dried. It is then oiled and heated over a coal-fire. In consequence of this treatment the steel portions appear in relief, the iron portions having been attacked by the corroding solution.

Damaskeened Surface upon Steel-guns.—The beautiful damaskeened surface exhibited by the Woolwich and Elswick steel-guns is produced by means of a special solution composed of the following ingredients: Tincture of steel, 2 ozs.; nitric acid, 1 oz.; sulphate of copper, 1 oz.; spirit of nitre, 1½ ozs.; spirits of wine, 1½ ozs.; and water, 1 gallon. This solution is smeared over the parts, and when dry another coat is put on, the result being a fine brown color which, if not dark enough, is made so by a repetition of the operation, six coats being sufficient to make the surface

black. The acid is then killed by washing with soda solution, and the whole rubbed with a hard brush until smooth, after which it is rubbed with oily waste. Other solutions for this purpose are in use at some establishments of high repute, one of the most important of these consisting of a mixture of 1 oz. each of sulphur, tincture of steel, nitric acid and spirit of nitre with ¼ oz. of sulphuric acid, ½ oz. each of mercuric chloride and sulphate of copper, and 1 quart of water.

Damasked Bronze.—By this term are understood bronze articles engraved with quite deep lines which are inlaid with silver or gold wire, pressed in by means of a burnishing stone or small hammer. The articles are finally polished and have a beautiful appearance, the gold and silver designs upon the bronze ground presenting frequently a striking resemblance to embroidery.

Iridescent Colors upon Metals.—To produce rainbow colors upon gilt articles of iron, brass, and other metals, as well as upon clean metallic surfaces in general, they are treated as follows: Prepare a bath by boiling for half an hour 3½ ozs. of caustic soda, 14½ drachms of litharge and 1 quart of water. Connect the object to be colored, which must be previously thoroughly cleansed and pickled, with the wire of the positive pole of a battery, and use a platinum wire as anode. By dipping the platinum wire in the bath without touching the article, the latter becomes immediately colored with various colors originating from a more or less thick layer of the precipitated oxide of lead. Colors of all possible contrast can be obtained by placing vertically a piece of stout parchment paper between the articles to be colored and the platinum wire, and also by providing the parchment with numerous holes or radical segments.

Moiré Metallique.—To give tin-plate and articles manufactured from it a crystalline surface, it is polished by hammering and then heated over a coal-fire so that the tin melts, however, without oxidizing. It is then removed, and the side which had been exposed to the fire is poured over with water from a vessel so arranged that a broad stream can be brought upon the surface. In cooling the tin crystallizes, but the surface presents a poor appear-

ance, and must, therefore, be further treated with acid. The sheet is placed in a mixture of 1 part of nitric acid, 2 of hydrochloric acid, and 3 of water, whereby the tin upon the surface is in a short time dissolved. The sheet is then taken out, washed first in caustic potash-lye, which considerably enhances the metallic lustre, and, after rinsing in clean water, dried at a moderate heat, and finally coated with transparent copal lacquer. By certain manipulations the direction the crystallization is to take may be determined. By drawing, for instance, with a hot soldering-iron designs upon the back of the heated and cooled plate, the tin melts through the plate, and by the action of the acids the design is recognized upon the other side by the changed direction of the crystallization. By heating tinned sheet-iron over the flame of a spirit-lamp the tin fuses all around, and forms a round spot whose circumference becomes the larger the longer the sheet remains over the flame. On removing the flame the place where it was applied will be recognized as the centre of a stellated crystallization. Pure tin is best adapted for this purpose. The moiré is as a rule obtained by exposing tin or tin-plate, previously carefully cleansed, to the action of hydrochloric, sulphuric, or nitric acid, or other chemical reagents of not too strong action, and finally freeing the surface covered with moiré as much as possible from the oxides produced during the operation.

I. Pour into a clean and dry glass or porcelain vessel 80 parts by weight of ordinary sulphuric acid, and add 10 of ammonium chloride, sodium chloride, etc., and immediately cover the vessel with the sheet to be treated, allowing it to remain as long as effervescence continues. It is then removed, washed by immersing in ordinary water, and dried with fine linen, or allowed to dry by itself. This operation is repeated five or six times in succession until a moiré of desired purity and beauty is obtained.

II. By immersing tin-plate in sulphuric or hydrochloric acid for two or three minutes and thoroughly rinsing in ordinary water, it will be found covered with moiré.

III. A very white and lustrous moiré is obtained by boiling tin-plate in sulphuric acid diluted with ten times its volume of water

for half an hour, then rubbing with a soft woollen rag dipped in a solution of equal volumes of cold water and sulphuric acid, washing and finally rinsing in cold water.

IV. First wash the plate with a soft rag saturated with a mixture of equal volumes of alcohol and oil of turpentine. After thoroughly rubbing the entire surface, wash with pure alcohol and dry with clean linen. Now take the yelks of 12 fresh eggs, and rub them up carefully in a mixture of 12 teaspoonfuls of hydrochloric acid and a like quantity of water. When the composition has acquired the consistency of a stiff paste, add 12 teaspoonfuls of nitric acid, which renders the mixture more fluid. Now dip a pad of cotton or other soft stuff in the fluid, and rub the surface of the metal, being careful to carry the pad quickly and lightly over all parts, so that the composition is everywhere uniformly applied, but not allowed at any point, to dry. When the designs show well and the moiré has acquired a good lustre, so that neither a stain or an inequality of color is observed, wash with a woollen rag strongly saturated with a mixture of equal parts of hydrochloric and nitric acids and 5 parts of water, and, after washing in an abundance of water, allow the article to dry. By adding to the acid mixture diluted with water a small quantity of trichloride of gold, the gold precipitates in the form of oxide, and imparts to the moiré more beauty and lustre.

Colored Moiré on Tin-plate.—Heat the tin-plate to a temperature at which the tin begins to melt, and then immerse it quickly in a fluid composed of hydrochloric acid, 2 parts; nitric acid, 1; water, 3; and potassium bichromate, 1; deep black spots are produced, which become still darker by adding some tin salt. By now thoroughly rinsing the sheets, pouring hydrochloric acid over them, which is allowed to run slowly from the sheets, so that only a slightly acid fluid remains, and finally pouring over a solution of 10 parts of sodium hyposulphite in 120 of water, crystals playing into various colors, according to the longer or shorter time of the action of the solution, are obtained. The articles are finally rinsed in water, then in alcohol, and coated with a suitable varnish.

Moiré on Brass,—To produce moiré on brass, boil the objects in

a concentrated aqueous solution of blue vitriol (1 part blue vitriol to 2 parts water) for some time. The shades obtained vary according to the proportion of zinc and copper in the brass. If an article when taken from the solution appears dark red or dark violet without perceptible reflections, it is only necessary to rub it with a little wax-varnish or rosin-varnish. The formation of moiré is much promoted by putting a few small pieces of iron in the solution.

To Decorate Tin-plate.—Lithographs upon tin-plate or other metal sheets are frequently produced by directly printing the sheets in the lithographic press. More elegant results are, however, obtained as follows: The design is printed in black color, to which some copal lacquer has been added, upon sheets of paper, the size of the sheets to be decorated, which have been prepared with paste, gum, and glycerin. The paper, printed side down, is immediately laid upon the sheet, and passed together with it through the press; it is then dampened with a wet sponge, and again passed through the press. To save time, the production of the lithograph and its transfer to the metallic sheet is frequently combined as follows: Lay the paper upon the stone, upon the paper a leather-plate, and upon the latter the sheet with the last-printed paper, and pass the whole through the press. When the sheet comes from the press the paper is again dampened, and then carefully drawn off, whereby the design in its finest details remains upon the sheet. The sheets are now placed in an oven, heated to 284° F. for 12 hours, then coated with a mixture of copal lacquer, oil of turpentine, and linseed-oil varnish, and again placed in the oven for 12 hours. When directly printing the sheets from the stone some asphalt or iron lacquer is added to the printing-ink, and for other colors some dammar lacquer, in order to obtain better lustre and to promote drying. The printed sheets are dried in the oven until the color cannot be wiped off, care being had, however, not to raise the temperature to the melting-point of the tin. When dry, the prints receive by means of a flat, broad, soft brush a uniform and not too thick coating of a mixture of 1 part of linseed oil and 2 parts of dark copal lacquer, and are then again dried in the oven for one hour. This coating imparts to the sheets the lustre and color of

polished brass; its principal advantage being, however, that it does not crack off when bent, so that the decorated sheets can be worked in every way, and even hammered.

New Method of Decorating Metals.—This invention of Nellie C. Duncombe, of New York city, presents a beautiful field for taste, skill and industry, and it has been carefully fenced in by the patent issued July 16, 1889. The decorative design is formed upon the metallic surface by means of etching and oxidation of the metal. Suppose the plate to be decorated to consist of polished sheet brass, all those portions which are finally to appear as polished surfaces—the high lights or, perhaps, the outlines of the design—are covered with a brush dipped in a suitable varnish. When the varnish is dry the plate is immersed in a bath of nitric acid somewhat diluted, in which is a small piece of copper in process of dissolution. By this immersion the surface of the plate is both etched by the acid and discolored by the action of the copper which is dissolved by the acid. After a few moments' immersion the plate is removed and rinsed. As it dries in the air the exposed surface becomes a dull brown, like old bronze. All the portions that are to retain this color are then painted with the same varnish and the plate is then dipped in a weak solution of copper salt. This brightens the surface and gives it a yellowish, mottled appearance. Then the plate is dried in fine saw-dust, box-wood preferred. After protecting with the varnish so much of the color as it is desired to retain, the plate is again immersed in the same nitric acid bath until it has been sufficiently etched to remove the previous oxidation, again rinsing and holding it, either side up, over a tray containing diluted nitric acid and pieces of copper and sheet brass. After being left to be oxidized in these fumes a few moments, the plate is again dried in saw-dust, and the result is an orange-color somewhat mottled. Again painted and exposed for a longer time to the fumes of the acid, copper and brass, a green color is produced. Again dried in the saw-dust and painted as before, a frosted effect is produced on the unpainted portion that is left by a quick dip in a bath of nitric and sulphuric acids and water, after which it is rinsed and dried quickly in hot saw-dust.

The varnish is now removed with turpentine or another solvent and the entire design is exposed, and the plate is completed.

It is immaterial, after painting over the high lights, in what order the successive oxidations are produced, but it is preferable to oxidize the finer and more delicate portions of the design first and finish with the ground etching. The depth of the etchings is of no consequence, the color, like beauty, being only skin-deep.

The varnish preferred for the operation is made as follows: Asphalt, 2 ozs.; white wax, 1½ ozs.; Burgundy pitch, 1 oz., and a sufficient quantity of turpentine. Melt the asphalt in a glazed saucepan and add the wax gradually, stirring with a glass rod, add the pitch and continue stirring, permitting it to boil up twice or three times, but never let it boil over. Take the saucepan from the fire and stir in enough turpentine to make the mass the consistency of tube oil paints. Other colors, such as dark purple or orange, red and green, green bronze and light green, bright green and red, bright pink, iridescent purple, may be made by the same method with various kinds of baths.

Nielled Silver.—This term is applied to silver articles provided with a black etching. The articles are produced by first engraving them quite deeply and inlaying the lines with a black enamel consisting of metallic sulphide. The niel consists of a mixture of sulphide of silver, sulphide of copper and sulphide of lead. The older niel was generally rich in silver, but in the modern the sulphur combinations of copper and lead preponderate. To prepare the niel fuse first the sulphur in a graphite crucible and heat until the sulphur boils. Heat a certain quantity of silver and copper, which are best used in the form of wire or thin sheet; throw first the silver into the crucible, then the copper and finally the lead, the latter in pieces the size of a pea. Stir the mass with a clay rod to intimately mix the metallic sulphides and examine whether there are still unmelted parts in the crucible. When all is melted pour the mass quickly into water, which imparts to it a certain degree of brittleness. Then powder the niel as finely as possible in a cast-iron mortar, separating the fine from the coarse powder and

again pulverizing the latter. The proportions generally used are as follows:

	Parts.				
Silver	8	2	1	1	2
Copper	18	5	6	2	1
Lead	13	7	10	4	
Sulphur	96	24	36	5	3

According to Hart the niel consists of 4 parts of fine silver, 9 of pure copper, 1 of platinum (which is, however, not absolutely necessary), 2 of borax and 48 of flowers of sulphur. First melt the silver, then add the copper and, when both are liquid, the lead. The melted metals are stirred with a stick of charcoal to insure homogeneity. The mixture is then poured into a large crucible containing the pulverized sulphur. The crucible is then replaced upon the fire for a few minutes to keep the mass fluid. It is then poured over brushwood into water so that granules are formed. These granules are collected, dried in the air and then pulverized in a mortar.

The firm of Zachers, of Berlin, claim to have discovered the process of making the niel called Tula, after the Russian town of the same name. According to them the niel is prepared from 9 parts of silver, 1 of copper, 1 of lead and 1 of bismuth. The metals are melted and saturated with sulphur. This mixture gives the splendid blue which was formerly erroneously considered as steel-blue.

The article to be nielled having been prepared with the graver, by etching or stamping, is then dipped in a solution of borax. The pulverized niel is next made into a stiff paste with a concentrated solution of sal-ammoniac and pressed into the hollows by means of a spatula or brush. After wiping off the excess of niel with a moist cloth the article is allowed to dry, after which it is to be heated.

This is effected with single small objects over glowing coals, but if a larger number of objects are to be treated they are placed upon sheet-iron and brought into the glowing muffle of an enamelling furnace. When the niel is fused the iron plate with the articles is

taken out and after cooling the pattern is uncovered by a level grinding with pumice stone, when the silver will appear as over a black ground. Polishing is effected with the same agents and in the same manner as that of other silver objects. A cheaper method than by engraving each article by itself is to engrave in relief a steel plate and press it against the silver plate between two hard bodies. The copy is hollow and ready to receive the niel. A great many copies may be obtained from the same matrix.

The muffles which serve for the reception of the objects to be

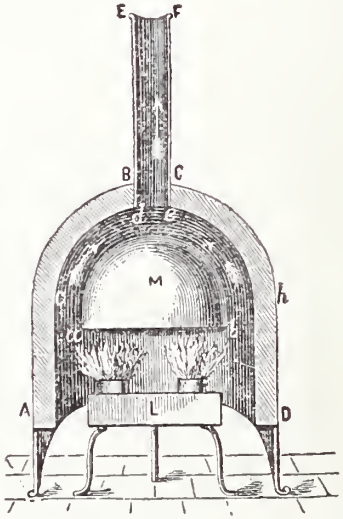


Fig. 20.

nielled and enamelled consist of semi-cylindrical bodies generally made of refractory clay. On one of the wider sides they are provided with a large opening and on one of the narrower sides with a small round aperture. The large aperture is closed with a clay plate after the objects have been placed in the muffle. In the small aperture is secured a tube which can be closed by a clay stopper. By removing the stopper the interior of the muffle can be watched through the tube, and the burning in of the niel or en-

amel controlled. An enamelling furnace with brass muffle, which is very suitable for working on a small scale, is shown in cross sections at Fig. 20; *M* is the muffle of stout sheet-brass. It is provided on one side with a lid which, with its projecting edges, can be pushed into the muffle. The furnace is constructed of double sheet-iron, and the space between the outer casing *A B C D* and the inner casing *c* is filled with a bad conductor (ashes, etc.). The casing rests upon four iron legs and is provided at *d e* with a small chimney. The muffle rests with both ends upon projecting edges of the inner casing. The furnace is heated either by gas or, as in-

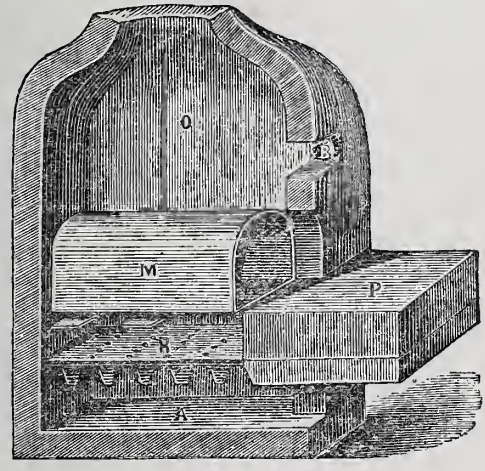


Fig. 21.

dicated in the illustration, by spirit flames. The size of the muffle as well as of the entire apparatus depends on the dimensions of the largest article to be decorated.

Another muffle-furnace is shown in Fig. 21. *O* is the actual furnace of refractory material, *M* the clay muffle resting either upon wrought-iron rails or upon projections of the furnace wall. *R* is the grate, *A* the ash-pit and *B* the aperture for introducing the fuel. In front of the muffle is a clay plate *P* which serves as a table in introducing and withdrawing the articles to be enamelled.

To Imitate Nielled Work by the Galvanic Method.—The design is executed upon the silver surface with a pigment consisting of white-lead and glue or gum water. The portions which are to remain free are coated with a protecting varnish and the design is then uncovered by etching with very dilute nitric acid. The article is then brought as the anode into a dilute solution of ammonium sulphide, and a small platinum sheet connected with the negative pole is dipped into the solution. Sulphide of silver being formed, the design becomes quickly black-gray and, after removing the protecting varnish with benzine, stands out in sharp contrast with the white silver.

Oxidized Silver.—This name is incorrect, as by it is understood, not an oxidation, but a combination with sulphur or chlorine. Solution of pentasulphide of potassium (liver of sulphur of the shops) is generally used for oxidizing silver. Liver of sulphur is prepared by intimately mixing and heating together 2 parts of thoroughly dried potash and 1 part of sulphur powder. Dissolve 2 or 3 drachms of the compound in 1½ pints of water, and bring the liquid to a temperature of from 155° to 175° F., when it is ready for use. Silver objects previously freed from dust and grease with soda lye and thorough rinsing in water, plunged in this bath, are instantly covered with an iridescent film of silver sulphide, which in a few seconds more becomes blue-black. The objects are then removed, rinsed off in plenty of fresh water, scratch-brushed, and, if necessary, polished. It is advisable to use the oxidizing liquid as soon as prepared. After it has been used for some time the deposit becomes dull and gray and lacking in adherence. There is danger in using the alkaline liquid too strong; the coating will form more quickly, but does not adhere so well.

The process is very readily executed upon pure silver, but with articles of cupriferous silver the result is not quite so beautiful, and it is, therefore, advisable to subject them to blanching before oxidizing.

A velvety black color is obtained by dipping the article previous to oxidizing in solution of mercurous nitrate, by which it becomes coated with a thin film of mercury, which forms an amalgam with

the silver. When brought into the liver of sulphur solution a mixture of mercury sulphide and silver sulphide is formed, which is much darker than silver sulphide by itself. By dipping the oxidized article into a liquid composed of 10 parts of blue vitriol, 5 of sal-ammoniac, and 100 of vinegar, the places of the silver left bright acquire a warm brown shade.

Another method of oxidation is effected by dipping the article into diluted chlorine water, chloride of lime solution, or into *eau de Javelle*. The action of these baths is based upon the formation of a thin layer of silver chloride, which, on exposure to light, becomes dark.

Beautiful effects and tasty designs may be produced by combining various shades of oxidation with the bright or gilded silver surface. By executing the design, for example, with asphalt lacquer and placing the articles in the liver of sulphur solution, only the places left free become oxidized, and the result, after removing the asphalt lacquer with oil of turpentine, will be a white design upon a dark ground. Dark designs upon a white ground are executed with ink prepared by thickening concentrated liver of sulphur solution by the addition of gum-arabic solution. When the design is dry the article is heated so that the gum cracks off or can be removed by a gentle tap. Black and light designs upon a dark gray ground are carried out by executing the first with asphalt solution and the latter with ink composed of mercurous nitrate and gum-arabic solution, and dipping the article into the liver of sulphur bath.

A yellow color is imparted to silver articles by dipping in a hot, concentrated solution of cupric chloride.

A deep black oxidized surface may be obtained directly on *copper*, properly cleansed, by immersion in a concentrated solution of hydrous carbonate of copper, either cold or tepid. The copper surface at once becomes coated with a fine black deposit, which will stand subsequent treatment very well. A fine oxidized surface may also be produced by depositing on the surface of the articles or on certain portions thereof a film of metallic platinum. For this purpose prepare a solution of platinic chloride in sulphuric

ether or alcohol, and apply the solution with a brush to the parts of the surface to be oxidized. The ether or alcohol speedily evaporates, leaving behind a film of metallic platinum adhering to the surface of the object, which film, according to its thickness, imparts to the surface either a steel-gray or nearly black lustre. A hot aqueous solution of platinic chloride will give the same results.

New Protecting Coat on Metals.—Two pounds of borate of lead are ground very fine with water. It is then allowed to settle, and, after pouring off the water, the deposit is mixed with a precipitate of platinum obtained by the addition of 1½ cubic inches of ammonia to a solution of 6¾ drachms of platinic chloride in 1 quart of water, allowed to settle for 3 hours, decanting the ammonia-water, replacing it by clean water, again allowing it to settle for 3 hours, and finally decanting the water. The platinum is ground together with the borate of lead for at least ½ hour; 5 quarts of water are then added, and the mass is ready for use. The articles of iron, steel, or copper to be coated, previously brushed or washed, are dipped in the preparation, or coated with it by brushing, and heated in a strongly heated muffle, or by a gas flame, until the originally white coating has acquired the color of dull iron.

Photo-chemical Process of Decorating Metal.—Breit, of Barmen, has patented in Germany a process according to which the metallic surface to be decorated—tabbied tin-plate is especially suitable for the process—is first coated with a colorless or colored alcoholic lacquer, and then, in a dark room, with a solution of chrome-gelatine. The latter is obtained by dissolving 5 to 10 parts by weight of gelatine and 1 to 2 of bichromate of potash in 100 of water. The gelatine possesses the peculiarity of losing its solubility in water by the action of light. Hence, by covering, after drying, the plate with the desired pattern and exposing it in a copying frame to the light, the layer of gelatine on the places exposed to the light becomes insoluble, while the parts covered by the pattern can be removed by placing the plate in warm water. After drying, the layer of lacquer first applied is removed from the places freed from gelatine with cold spirit of wine. The gelatine design remaining upon the plate may be colored as desired by placing the

plate in a dye-bath, the colored designs upon a bright ground thus obtained being fixed by lacquering. Before lacquering the metallic surfaces may be suitably provided with a patina, whereby the effect of colored designs upon a differently colored ground is obtained.

To Prepare Zinc for Painting.—Brush over the zinc with a solution of 1 part each of chloride of copper, nitrate of copper and sal-ammoniac in 64 parts of water and add to the mixture 1 part of commercial hydrochloric acid. After 12 to 24 hours the solution dries to a dull gray color. Painting upon this surface the colors will adhere in a perfect manner. Another process is as follows: Into some hydrochloric acid of full strength drop pieces of zinc until effervescence ceases. Add an equal quantity of water and with a sponge tied to a stick wash over every part of the surface to be painted. This roughens the surface and takes off that sort of greasiness which prevents paint from adhering. After the acid has remained a short time on the zinc wash with water or dilute vinegar, dry, and paint.

How to Prepare a Rough Surface in Grounding Metals for Subsequent Decoration.—The object of this process is to ground metals which are to be enamelled, or decorated with vitrifiable colors, or protected from tarnishing or rusting. The preparation of the surface to be enamelled is very simple and inexpensive; the enamel can be directly and uniformly applied without the necessity of using a special ground mass and adheres very firmly without cracking or peeling off. The process is executed as follows: Mix finely pulverized iron-scale (magnetic oxide), or, still better, pure ferroso-ferric oxide prepared by precipitation, with more or less finely pulverized emery and triturate the mixture with a solution of lead or tin soap, adding a few per cent. of a readily fusible frit. Apply this mass to the metal to be grounded and burn it in. In burning in, the article may be heated to a red heat, whereby a fine violet-blue coating, rough to the touch, is obtained, which, without further preparation, can be dipped into the covering mass, enamelled or painted with vitrifiable colors, and burnt in. By this treatment the rough violet-blue coating formed from the lead solution and the magnetic iron mixed with emery constitutes the

ground mass for the enamel and colors. By the foregoing described method of grounding, articles of all kinds, of cast-iron as well as of wrought-iron, can be provided with a very durable enamel. By increasing the quantity of magnetic iron a ground mass for a very refractory covering mass may be made.

To Coat Stoves, Tools, etc.—Metallic tools and other articles, particularly those of iron and steel which are used in laboratories and other workshops where acid vapors are of frequent occurrence, can be protected with a lustrous black coat which resists acids, and is but little affected even by a low red heat, as follows: Have a sheet-iron box constructed large enough to hold all the articles to be coated, and provided with a false bottom of wire netting about 1½ inches above the actual bottom. Underneath this wire netting is placed a layer of crushed blacksmith's coal about ¾ inch deep; then place the articles, which must be entirely free from rust, clean and polished, upon the wire net. The box is then covered with a well-fitting lid and set on a strong fire, which causes the coal to give off tarry constituents, the heat being continued until the bottom of the box is at a red heat. When all evolution of gas has ceased the box is allowed to become cold, and the articles are taken out, and will be found covered with a beautiful glossy coat.

Ward's Inoxidizing Process.—This process is based upon the simultaneous employment of silicates and heating. The cast- or wrought-iron articles are coated by means of a brush or by immersion with a silicate. This coating dries quickly, and when the articles are exposed to a suitable heat liquefies, penetrates the pores of the metal, and after cooling forms a dense uniform coating of a dead-black color, which does not change by the action of the atmosphere nor crack off from the article. By adding to the silicate pigments used for coloring glass, decorated surfaces of great beauty may be obtained, which are far superior to those produced in the ordinary manner by the application of paint.

Inoxidizing Process for Cast-iron.—The cast-iron articles, entire gas-chandeliers, water pipes, ornamental pieces, railings, kitchen-pots, etc., are placed upon an iron carriage and first exposed in a reverberatory furnace of special construction at a temperature of from

"Coslettising" Engineer 28/10/1910

A rust-proofing process for iron and steel has recently been tried which consists in boiling the iron or steel article to be treated in a solution of one gallon of water, four ounces of phosphoric acid and one ounce of iron filings. By this means a black coating is produced, which protects the article from atmospheric and other corrosive influences.

It is stated that a piece of steel treated and immersed in salt water for nearly a year has resisted its attacks; so that it is practically free from corrosion, while a similar piece untreated has become badly rusted.

1112° to 1292° F. for 15 minutes to the oxidizing, and then for 20 minutes to the reducing action of gas generators. After removal from the furnace and cooling, the inoxidized articles acquire a uniform slate color; they may, however, be enamelled and decorated in any manner desired. In applying the enamels pickling with acid is not necessary, and consequently the enamel adheres very firmly. Various articles exposed in the open air for two years to all kinds of atmospheric influences showed no trace of deterioration. Numerous experiments have demonstrated that the tensile strength of the iron is but little decreased by inoxidation, in fact, no more than by annealing. As regards the durability of the surface layer with a high load, it has been determined that from wrought-iron bars it cracked off in the form of small lamina with an average tension of 4025 lbs., but from cast-iron it did not crack off even with a breaking load.

The Barff Process for Preserving Iron and Steel from Rust.—Barffing is so called from the name of its discoverer; and its purpose is to render the surface of metallic articles treated, resistant to acids and impervious to humid oxidation. Iron and steel that have been properly barffed will not rust. The process belongs in no sense to the chemical laboratory, and requires no particular scientific knowledge or technical skill for its success. Highly polished work retains its finish after the process, although the treatment changes the shining polish to a dark slate color. But working parts, such as sliding and rubbing surfaces, retain their smoothness, and work as freely after as before the process; plugs, valves, and stems for cocks, gates and faucets, for instance, working just as smoothly as though they had not been barffed.

The articles to be treated are made perfectly clean—free from oil and dust—and are placed in a muffle, an air-tight oven, into which is led a steam-pipe from a boiler that carries steam at a pressure of from 60 to 100 pounds to the inch. This pipe, after leaving the boiler, becomes a coil in a furnace in which it is kept at a red heat. Of course, the steam that is discharged into the muffle is what is known as "red-hot steam," or steam highly superheated. The effect of this steam on the articles exposed to its action is to

convert their surfaces into magnetic oxide of iron, this change reaching to an appreciable depth, giving to the surface the hardness of steel with the durability of gun-metal. It has been said that the surface of the metal is changed to an "appreciable depth," perhaps it would be more precise to say, that this magnetic oxide adds to the surface; for micrometer tests show that the article is absolutely larger after being barffed than before undergoing the process.

Pieces which are to work together, therefore, as the plug and barrel of a cock, are fitted to allow for this increase, the plug being finished somewhat smaller than it would have been if it was to be used in its lathe-finished state. The only limit to the size of the pieces to be barffed is the capacity of the muffle.

Enamelling Metals.—In enamelling metals, transparent or opaque, colored or plain enamels are fused by heat upon the surface of the object and incorporated by fusion with its surface. Enamel for metals must, therefore, be indestructible by heat. A good enamel for coating iron utensils should firmly adhere to the surface, withstand slight shocks and be capable of resisting changes of temperature and chemical influences. Besides it should not be too refractory and should fuse at a lower temperature than the metal to be coated. To enable the enamel to follow the expansion and contraction of the iron, and to stand changes of temperature, two kinds of enamel fusible at different temperatures are applied in enamelling iron utensils. The first layer is called *ground* or *ground mass*, and consists of an aluminium silicate containing frequently as much as 75 per cent. of silicic acid. The refractoriness of the ground mass is besides frequently decreased by the addition of boric acid and alkalies, and its adhesion to the iron promoted by a small content of magnesia. For enamelling articles not to be used for culinary purposes, the refractoriness of the ground mass may be decreased by the addition of oxide of lead. The ingredients for the preparation of the ground mass are fused, and after cooling, pulverized and ground until a uniform, fine powder is obtained.

The *covering mass*, or *glaze*, contains less silica and alumina and

is therefore more readily fusible than the ground mass. It is rendered opaque by the addition of zinc oxide.

Enamel for Iron Objects.—An enamel for cast and wrought-iron articles is obtained by fusing together 130 parts of finely pulverized crystal glass, 20½ parts of calcined soda and 12 of boric acid, and comminuting and finely pulverizing the fused mass. This enamel is glass-like, transparent and lasts well upon sheet-iron. Several layers of enamel of different degrees of fusibility may also be used for enamelling. The layer coming in direct contact with the iron is called "ground-mass." It fuses but incompletely, only the second layer, "the covering mass," fusing completely and imparting the requisite smoothness to the glaze. For preparing the ground-mass fuse together 30 parts of finely ground feldspar with 25 of borax, and after pulverizing the mass, mix it with 10 parts of clay, 6 of feldspar and 1¾ of carbonate of magnesia. Mix this ground-mass with water to a paste and apply it to the object to be enamelled. Then scatter upon it the covering-mass composed of a finely powdered and fused mixture of 37½ parts of quartz meal, 27½ of borax, 50 of stannic oxide, 15 of soda and 10 of saltpetre. The mass is uniformly distributed upon the object to be enamelled, carefully dried and burnt in in the muffle furnace. Other directions, especially for sheet-iron, are as follows: Silica or quartz, 30 to 50 parts; flint, 10 to 20; *or*, granite, 20 to 30 parts; china clay, 10 to 20; *or*, borax, 16 to 20 parts; pipe clay, 8 to 10; *or*, glass, 6 to 10 parts; chalk, 6 to 10; *or*, magnesia, 10 to 15 parts; porcelain meal, 5 to 15; *or*, feldspar, 5 to 20 parts; boric acid, 20 to 40; *or*, carbonate of soda, 10 to 20 parts; saltpetre or heavy spar, 6 to 10; gypsum, 2 to 8; fluorspar, 3 to 10. After fusing, the masses are finely ground and applied in thin layers, because on heating, the enamel and sheet expand differently. Cooling must also be effected very slowly since by cooling off too rapidly the enamel contracts unequally and cracks off.

To Enamel Cast-iron Utensils.—This is done in Lower Silesia by means of two masses, one for a ground and the other for a surface coat. For the ground-mass 110 lbs. of quartz, 50 lbs. of borax and 16½ lbs. of fluorspar are ground as fine as possible and

fused together in clay crucibles. Of the resulting mass 35 lbs. are then mixed with 14 to 27½ lbs. of quartz, 9 to 14 lbs. of gray clay and 1 lb. of borax. The composition is then, with water, formed into a paste, applied to the vessels and burnt in.

For the surface coat the following ingredients are mixed together: Fluorspar, 5½ lbs.; zinc oxide, 2¼; stannic oxide, 10½; bone meal, 1½; smaltine, 1 to 1½ ozs. To this are added: Fluorspar, 35¼ lbs.; borax, 20 to 21½ lbs.; sodium carbonate, 7 lbs.; nitre, 2¾ to 3¼ lbs.; and the mixture is fused in refractory crucibles with a hole in the bottom through which the liquid mass escapes into a vessel placed beneath the furnace. The mass, when cold, is pounded and ground, and 4 ozs. of washed white clay and ½ lb. of zinc oxide are added during the grinding process to every 66 lbs. of the mass. The composition is then applied like the first and burnt in.

In England a very white and firmly adhering enamel for cast-iron articles is prepared as follows: Keep the articles at a red heat in sand for ½ hour, cool off slowly and cleanse them with hot dilute sulphuric or hydrochloric acid, then rinse in water and dry. Next apply a ground-mass composed of flint glass, 6 parts; borax, 3; minium, 1; oxide of zinc, 1, finely powdered and roasted at a red heat for 4 hours, then rendered semi-fluid by increased temperature, then cooled in cold water and 1 part of it mixed with 2 parts of bone meal and made into a paste with water. When the coating on the article is dry apply a surface coat composed of a mixture of 32 parts of calcined bones, 16 of china clay, 14 of feldspar, 4 of potash, mixed with water, dried, cooled and, when powdered, made into a paste with 16 parts of flint glass, 5½ of calcined bones, and 3 of calcined quartz with sufficient water. When this second coat is dry, apply a mixture composed of 4 parts of feldspar, 4 of pure sand, 4 of potash, 6 of borax, 1 of oxide of zinc, 1 of saltpetre, 1 of white arsenic and 1 of pure chalk, mixed, calcined and cooled, and rubbed to a fine powder with 3½ parts of calcined bones and 3 of quartz. The coated articles are heated in a muffle in a furnace, which fuses the last two coatings and forms an adhesive and brilliant white enamel.

Another Method of Enamelling Cast-iron.—Scour the objects thoroughly with sand and dilute acid, rinse in water and dry. Then apply by means of a coarse brush a thin coat of gum-arabic, and scatter upon this, while still moist, the enamelling powder. For white enamel the powder consists of 130 parts of pulverized flint glass, 20 of calcined soda and 12 of borax, fused together in a crucible. The objects strewn over with this powder are dried at 176° F., and the powder is then liquefied in a suitably heated furnace. This coating adheres well and contains no injurious substances.

Mottled Enamel.—The composition of the enamel is as follows: Silica, 100 lbs.; soda-ash, 35 lbs.; borax, 75 lbs.; plaster of Paris or gypsum, 10 to 20 lbs.; and arsenious acid in the proportion of 1⅛ per cent. of all the other ingredients. When these are compounded the resulting mixture is an enamel vitreous enough to carry a glaze of itself, with an affinity for wrought or sheet-iron which causes it to adhere with extreme tenacity when burned upon it, and which will not exfoliate or absorb moisture in quantity sufficient to destroy its polish. The ingredients of the enamel having been comminuted, are carefully mixed together and brought to a state of complete vitrifaction in a reverberatory furnace. Then the enamel is run off as usual into water to granulate, when it is ready for grinding. In making an enamel for wrought or sheet-iron ware, 100 lbs. of the enamel are ground, adding about 5 lbs. of clay, preferably white, and having a pronounced soapy feeling, this clay helping to give body to the enamel and preventing its "crazing" when it is finally fixed on the iron in the heat of a muffle. It is advisable to introduce, along with the enamel and clay in the grinding process, calcined magnesia carbonate in the proportion of 8 ozs. to 100 lbs. of the enamel. The magnesia serves to make the enamel coat as finally applied less transparent, contributes to the flecking or spotting of it with white, and thus in a measure prevents the iron base from imparting to the enamel throughout its own dull and unattractive shade. Prepared as above the mixture is run through a strainer into tubs, where it is allowed to remain about one day, during which time a sort of ripening is

effected, when it is finally prepared as follows: The mixture being brought to about the consistency of cream by the addition, if necessary, of water, magnesia sulphate is added until the mixture is coagulated and pasty, yet still capable of being shaken out into a thin and uniform coat, 2 ozs. magnesia sulphate being usually sufficient for 100 lbs. of the mixture. The mixture having been finally prepared, the article is dipped into it, having been first prepared by the well-known processes of annealing, pickling, scouring and washing. For washing, clean water is used, the iron remaining therein until it is dipped. Care should be taken that the enamel is not laid on too heavily, and that it be evenly distributed. Having received a thin uniform coat by dipping, the article is dried, for if the enamel coat is burned while still damp it will crack or craze. This drying is accomplished for convenience and despatch in an oven constructed for the purpose, the range of heat in which varies from about 100° to 200° F., but it may be effected at summer heat in an ordinary close room. The higher the temperature the smaller and less distinct the spots; the lower the temperature the more pronounced the mottling. The time required depends on the thickness of the enamel coat, the quantity of moisture present, and the degree of heat employed. When thoroughly dried the coat is of a whitish color, and usually either brown or reddish-brown spotted; and when burned in a muffle is of grayish color, dark spotted. The burning process is effected in an ordinary muffle at a red, cherry-red, or slightly greater heat, the ordinary time required being about 4 minutes.

Enamel for Cast-iron Pipes According to Amtmann.—The ground mass consists of quartz, 34 parts; borax, 15; and soda, 2. The covering mass is composed of feldspar, 34 parts; quartz, 19; borax, 24; stannic oxide, 16; fluorspar, 4; soda, 9; and saltpetre, 3. The fusing of the covering mass requires a strong white heat for 20 minutes, and the outside of the hot finished pipes is provided with a coat of tar.

Glaze for Iron Pipes.—To protect iron pipes buried in the ground for a long time from destroying influences, it is recommended to coat them with a glaze composed of pulverized crystal

glass, 260 parts; soda, 41 parts; and borax, 24 parts. The carefully mixed ingredients are fused in a crucible, and, after cooling, the mass is converted into a very fine powder by pounding and grinding. The pipes to be coated are first cleansed by pickling in the usual manner, then washed and dried. They are next coated with a thin layer of solution of gum-arabic and then the powder is distributed over them by means of a sieve. To expel all moisture the pipes are next placed in a room heated to about 320° F., and finally heated to a red heat, at which the coat of glaze fuses. When the coating is uniform it adheres very firmly to the iron surface and resists all external influences. This process, called by the inventor, *Emaille de fer contre-oxydé*, may be recommended for iron pipes which are to possess special power of resisting external influences, but for general use it is perhaps too expensive.

Glass Enamel for Iron.—The articles, kitchen utensils, signs, etc., coated with this enamel, are not affected by atmospheric influences, nor destroyed by an ordinary fire, and do not rust.

Intimately mix 4 parts of powdered glass, 2 of spar, 1 of saltpetre and ¼ of a part of zinc oxide. Fuse them in a crucible and pour into moulds to cool. For use the necessary quantity is triturated with water. Heat the iron utensil to a red heat in a muffle furnace and apply the enamel, which will present a brilliant glassy appearance. To color the enamel *blue*, add cobaltic oxide; for *red*, ammonium; for *black*, manganic oxide; for *yellow*, uranic oxide; for *brown*, ferric oxide; for *green*, a mixture of 2 parts of stannic oxide and 1 of manganic oxide; for *pure white*, stannic oxide.

Enamel for Copper Cooking Utensils.—Powder and mix 12 parts of white fluorspar, 12 of unburned gypsum and 1 of borax, and fuse the mixture in a crucible. Pour the mass out, and, when cold, triturate it into a paste with water. Apply this with a brush to the inside of the vessel and place the latter in a moderately warm place so that the paste will dry uniformly. When dry, heat the vessel to such a degree in a muffle furnace that the paste which has been applied liquefies. When cold, the result will be a white opaque enamel.

Colored Enamels.—As a ground mass for colored enamels the following compositions may be used: Sand, 3 parts; chalk, 1; calcined borax, 3. This composition is especially suitable for pale red, purple and blue, but may also serve for other delicate colors, as it exerts no injurious influences upon the substances contained in the colors. A composition which, though it fuses with difficulty, may be used for any color is as follows: Quartz meal, 60 parts; alum, 30; common salt, 35; red-lead, 100; magnesia, 5. For painting on enamel it is best to keep on hand the various colors in the form of sad-colored vitrifiable pigments. For this purpose prepare a readily fusible enamel, which, however, must contain a covering body, such as oxide of tin or lead, and add the coloring oxides. After fusing the mass convert it into a coarse powder, which is again fused. This operation is continued until a uniformly colored pigment is obtained. The latter is then pulverized, mixed with oil of lavender and applied to a ground mass, consisting of pure white refractory enamel. When the picture is completed the object is carefully heated in the muffle so that only the colored composition fuses. When this is the case the heat is at once moderated to prevent the colors from running together. If the painting does not turn out well it may be effaced by careful scraping with a very hard graver and again covered by painting over; but it is very difficult to execute this operation in such a manner as not to injure the beauty and uniformity of the painting.

Enamels for Goldsmiths.—These differ from ordinary enamels in having a vivid lustre and a beautiful color, which must not suffer a change in remelting. As coloring agents metallic oxides by themselves or in mixtures are used as follows:

For *blue*, oxide of cobalt; for *rose-color* and *blue-gray*, oxide of gold; for *white*, oxide of tin; for *yellow* and *brown*, oxide of uranium; for *yellow*, *red* and *brown*, oxide of iron; for *yellow* and *blue-green*, oxide of chromium; for *violet* and *brown*, oxide of manganese.

The enamels are finely pulverized and made with water into a

thin paste. After having been applied to the metal and dried, they are burnt in the muffle, and, after cooling, polished.

White Enamel for Ornamental Articles.—Calcine together and convert completely into oxide 2 parts of tin and 1 of lead. Mix 1 part of this oxide mixture with 2 parts of pulverized white crystal glass, and after adding a very small quantity of saltpetre or pyrolusite as a decolorizing agent, fuse in a small crucible, and pour the fused mass into cold water. Repeat the fusing twice or three times, or until the mass is no longer blistered, but thoroughly homogeneous. It is then rubbed to a fine powder, and may be applied either by itself, or, for small surfaces, by mixing it with oil of lavender and laying it on, like oil paint, with a brush. For the preparation of white enamel with a lower fusing point, the following composition may be used: 100 parts of the tin-lead oxide, 60 of pure quartz meal, and 25 of common salt. In place of pure quartz meal sand may be used, which must, however, be subjected to purification, in order to yield a white product. For this purpose calcine 100 parts of sand with 25 of common salt. The iron contained in the sand combines with the chlorine of the common salt to a combination which evaporates on heating, and a fritted mass sufficiently free from iron remains behind. The sand is then mixed with 25 parts of red-lead and fused. In this manner a fritted mass representing a lead-soda glass is obtained. To prepare enamel with this mass, it is finely pulverized and mixed with a zinc oxide, or with the mixture of tin oxide and lead oxide, by using 100 parts of oxide to 50 of the frit. The larger the quantity of tin oxide in the enamelling mass the thinner the coating may be. Enamelling masses containing no tin oxide may also be prepared, sodium antimonate being generally used in this case. A composition giving a very beautiful enamel consists of a mixture of 3 parts of crystal glass, 1 of sodium antimonate, and a very small quantity of saltpetre. In preparing all these kinds of enamel care must be had in fusing to prevent the action of reducing bodies in the crucible by closing the latter with a well-fitting lid. If fire gases penetrate into the crucible, enamelling masses of inferior quality are obtained.

Emaille Cloisonnée.—The work known under this name is executed in a peculiar manner, generally upon copper or gold, and gives an enamel of unlimited durability. The outlines of the design to be executed in enamel are chiselled in the surface of the metal, so that a very narrow plate of metal remains standing between the boundaries of enamel of a determined color. The place inside of the outlines is chiselled out with a graver, and the surfaces remaining standing are made as rough as possible, in order to offer a good hold to the enamel. For articles of gold the outlines for the enamelling masses are frequently formed of thin strips of sheet gold, which are placed upon the plate and fused together with it by heating. In the cavities prepared in this manner the enamelling mass mixed to a thick paste with oil of lavender or water is placed, the application and fusing of the mass being repeated until the cavities are entirely filled. Enamels of various colors can be used, each color being terminated by the edges of the cavities, and after heating the articles appear coated with the firmly adhering enamel. After the last fusing of the enamel the object is ground and polished.

Enamelling Watch-dials.—Thin sheet-iron is cut into the desired shape and pressed, the edges being raised to prevent the enamel from running off when in a fluid state. The plate is then cleansed. The proper proportion of the enamelling mixture is as follows, though in many cases and for special purposes it may be slightly modified: White-lead, 12 parts; arsenic, 2½; crystal glass, 8; saltpetre, 3; borax, 6¾; flint, 2. The ground ingredients are mixed, fused in a crucible, and while hot chilled in cold water, which renders the mass easily broken. It is next crushed to the fineness of coarse sand, washed, dried, and is then ready for use. The cleansed and dried dials are scattered over, according to the desired thickness of the coating, with more or less of the powder, and then placed in a muffle. Lettering and figuring may be executed in the usual manner. If they are, however, to be put upon the cold enamel they are printed on the dial with soft black enamel by transferring. The dial is then again placed in the muffle to fuse the enamel of the lettering and figuring. The color

of the enamel may, of course, be varied by the addition of different salts and earths, for instance, by cobalt, peroxide of manganese, peroxide of iron, etc.; a similar variation of color for the lettering and figuring being also possible.

Emaille Plaque-vitro-metallique.—The articles are first treated in exactly the same manner as given under "*Glaze for Iron Pipes*," and after burning in of the enamel, coated again with a solution of gum. Upon this coating of gum are then placed very thin leaves of beaten metal—copper, gold, silver, platinum, etc.—and burnt in.

Emaille-champ Levée is prepared by stamping thin gold sheets with steel dies, filling in the depressions thus made with enamel, and burning the latter in.

Phosphorescent Enamel.—Commercial phosphorescent paint in powder is intimately mixed with ⅔ of its weight of very finely pulverized fluorspar or cryolite and ⅓ of calcium borate. The mixture is made into a paste with water, and applied in a uniform layer to the articles to be enamelled by means of a brush. They are then burnt in the usual manner.

To Secure Enamel and Glass to Metal by Means of the Electric Current.—The enamel, pieces of glass, etc., arranged upon a perforated metal support, are immersed in a metallic solution (of copper, zinc, gold, etc.), and an electric current is conducted through the latter. The current effects a separation of the metal in the solution, which fills up the spaces between the enamel, pieces of glass, etc., and the perforations of the support, whereby a durable union with the metallic support is effected.

Engraving on Copper.—This is executed by cutting lines representing the subject on a copper plate by means of a steel instrument, called a graver or burnin, ending in an unequal-sided pyramidal point. Besides the graver, the other instruments used in the process are a scraper, a burnisher, an oil-stone and a cushion for supporting the plate. In cutting the lines on the copper the graver is pushed forward in the direction required, being held at a small inclination to the plane of the copper. The use of the burnisher is to soften down the lines that are cut too deeply and

for burnishing out scratches in the copper; it is about 3 inches long. The scraper, like the burnisher, is of steel, with three sharp edges to it; it is about 6 inches long, tapering towards the end. Its use is to scrape off the burr raised by the action of the graver. To show the appearance of the work during its progress, and to polish off the burr, engravers use a roll of woollen cloth or felt, called a rubber, which is used with a little olive oil. The cushion, which is a leather bag about 9 inches in diameter filled with sand, for laying the plate upon, is now rarely used except by writing engravers. For architectural subjects or for skies, where a series of parallel lines is wanted, a ruling-machine is used, which is very accurate. This is made to act on an etching ground by a point or knife connected with the apparatus, the lines thus made being bit-in with nitric acid in the ordinary way.

The copper plate must be perfectly polished, very level, and free from any imperfection; to this must be transferred an exact copy of the outlines of the drawing. To do this the plate is uniformly heated in an oven or otherwise till it is sufficiently hot to melt white wax, a piece of which is then rubbed over it and allowed to spread so as to form a thin coat over the whole surface, after which it is left in a horizontal position till the wax and plate are cold. A tracing of the original design having been taken with a black lead-pencil on a piece of thin tracing paper, it is spread over the face of the prepared plate, with the lead lines downwards, and being secured from slipping, a strong pressure is applied, by which operation the lead lines are nearly removed from the paper, being transferred to the white wax on the plate. The pencil marks on the wax are now traced with a fine steel point so as just to touch the copper; the wax is then melted off, and a perfect outline will be found on the copper, on which the engraver proceeds to execute his work.

Engraving on Silver or Gold.—I. The engraving is first exposed to the vapor of iodine, which deposits upon the black parts only. The iodized engraving is then applied with slight pressure to a polished plate of silver or silvered copper. The black parts of the engraving, which have taken up the iodine, part with it to the

silver which is converted into an iodide at those parts opposite to the black parts of the design. The plate is then put in communication with the negative pole of a small battery and immersed in a saturated solution of sulphate of copper, connected with the positive pole by means of a rod of platinum. Copper will be deposited on the non-iodized parts corresponding to the white parts of the engraving, of which a perfect representation will thus be obtained; the copper representing the white parts and the iodized silver the black parts. The plate must be allowed to remain in the bath for only a very short time, for if left too long, the whole plate would become covered with copper. The plate, after having received the deposit of copper, must be carefully washed, and afterwards immersed in a solution of sodium hyposulphite to dissolve the iodide of silver, which represents the black parts; it is then thoroughly washed in distilled water and dried.

II. Heat a silver plate, previously coated with copper, to a temperature sufficient to oxidize the surface on the copper, which successively assumes different tints, the heating being interrupted when a dark brown-color is obtained. It is then allowed to cool, and the exposed silver is amalgamated, the plate being slightly heated to facilitate the operation. As the mercury will not combine with the oxide of copper, a design is produced of which the amalgamated parts represent the black, and the parts of the plate covered with oxide of copper the white ones. The amalgamation being complete, the plate is to be covered with three or four thicknesses of gold-leaf, and the mercury is evaporated by heat, the gold adhering only to the black parts. The superfluous gold must then be cleaned off with the scratch-brush; after which the oxide of copper is dissolved by a solution of nitrate of silver, and the silver and copper underneath are attacked with dilute nitric acid. Those parts of the design which are protected by the gold, not being attacked by the acid, correspond to the black parts of the plate; the other parts corresponding to the white parts of the engraving may be sunk to any required depth. When this operation is com-

pleted the plate is finished and may be printed from in the ordinary method of printing from wood-cuts.

To Engrave Aluminium.—One of the many interesting peculiarities of aluminium is its resistance to the direct action of the graver; the tool slips off like from a hard surface of glass. However, by using a varnish of 4 parts of oil of turpentine and 1 of stearin, mixed with 1 of rum, the graver penetrates the aluminium like pure copper.

Soft Wax for Engravers.—Melt together tallow, 1 part, and yellow wax, 2 parts; *or*, olive oil, 1 part, and yellow wax, 5 parts; *or*, turpentine, 1 part, and yellow wax, 4 parts; *or*, yellow wax, 5 parts, and Venetian turpentine, 3 parts.

Wax-mass for Copper Engravers.—As an excellent coating for copper plates which are to be engraved, the following mixtures can be especially recommended: *For work in winter:* Yellow wax, 40 parts; mastic, 30; asphalt, 15. *For work in summer:* Yellow wax, 120 parts; mastic, 30; asphalt, 60; amber, 30. Melt the asphalt and the wax, each by itself, and, after allowing the mastic to dissolve in the wax, mix both substances together with constant stirring. For use the mass as well as the copper plate must be heated, the latter for the purpose of making the ground adhere more firmly.

Etching-ground.—I. White wax, 1 part; mastic, 1 part; asphalt, ½ part. Pulverize the mastic and asphalt, each by itself, melt the wax in an earthen pot over a fire, and when very hot add, with constant stirring, first the mastic powder and then the asphalt powder. Continue the stirring until the asphalt is completely melted, then remove the pot from the fire, allow the mixture to cool, and pour it into clean warm water. While in the water knead the mixture with the hand, and finally form it into small cylinders or balls, which are kept for use wrapped in taffeta.

II. Mastic, 2 parts; asphalt, 1.

III. White wax, 3 parts; asphalt, 4; black pitch, 1; colophony, 1. First melt the wax and pitch, next add the colophony and asphalt, and then boil until a sample after cooling readily breaks

on bending. In melting, a carbonizing heat should be strictly avoided.

Callot's Etching-ground consists of pure linseed-oil varnish, which is heated in an earthen pot, and mixed with an equal weight of powdered mastic, the mass being constantly stirred. When intimately melted together the mixture is filtered through fine linen into a bottle. For use the mixture is applied to the heated plate by means of a brush, and after smoothing the coat with a tuft of cotton it is dried by being held over the heated plate, until the varnish ceases to smoke.

Etching on Copper.—For coating the plates ordinary etching-ground is used, while pure nitric acid with ⅓ water, poured ½ centimetre deep upon the plates, serves as corroding solution. *Callot and Piranesi's corroding solution* acts, however, with greater uniformity. It is prepared from wine vinegar, 8 parts; verdigris, 4; common salt, 4; alum, 1; and water, 16. A corroding solution which can be highly recommended is prepared as follows: Dilute 10 parts of fuming nitric acid with 70 of water, and add a boiling solution of 2 parts of potassium chlorate in 20 of water. For etching slighter portions, the solution may be further diluted with 100 or 200 parts of water. Deeper places are produced by allowing the corroding solution to act for a longer time, or by the addition of fluid of greater strength.

Etching on Brass and Silver is executed in the same manner as on copper.

Etching on Steel.—Fine lines are produced in 1 to 2 minutes, and the strongest lines in 15 minutes, by a corroding solution composed of 4 parts of pyroligneous or ordinary acetic acid, to which is subsequently added 1 part of rectified alcohol. A mixture of 3 ozs. of warm water, 4 grains of tartaric acid, and 4 drops of nitric or sulphuric acid may be used for very soft steel. Many metallic solutions diluted with the necessary amount of water may also serve as corroding solution, they having the advantage of no bubbles being formed. Among others may be mentioned the solutions of stannates, bismuth nitrate and cupric nitrate, though with the use of the latter the precipitating copper exerts an injurious

influence. For fine lines *Humphry's mixture* is used; it is prepared by dissolving ¼ oz. each of corrosive sublimate and alum in 1 quart of hot water. After cooling the solution is applied with a fine brush. The fine lines are produced in about 3 minutes. The corroding solution having acted sufficiently it is poured off and the plate washed with alcohol diluted with 4 parts of water. To prevent any further action of remaining traces of corroding solution, the lines are filled, by means of a brush, with oil of turpentine containing some asphalt in solution, and the plate is protected from rust by a coat of caoutchouc varnish or of mutton-suet.

Etching Names on Steel and Glass.—With equal quantities of cupric sulphate (blue vitriol), sodium chloride (common salt), well powdered and mixed together, names or other marks can be etched on steel surfaces. The wax process must be used, although soap will answer, or any other substance not acted upon by acids. Spread the beeswax or soap in a thin, even coating over the article to be etched, and with a sharp-pointed awl write or draw the design upon the wax-covered surface. Every line must be cut cleanly, and every particle of the coating removed, otherwise a break will appear in the etched line. When the drawing has been made satisfactory, put a "tinker's dam" around the wax-covered spot; this is done by rolling out a piece of putty into a long, thin roll, bending it around the wax-covered spot and pressing it lightly down, thus making a little reservoir to hold the acid or other corroding substance. Mix up the salt and sulphate of copper, fill inside the dam, and moisten with water to hasten their action. When satisfied that the etching is deep enough, or tired of waiting for it to work, wash off the corroding mixture and scrape off the wax, or dissolve it away with turpentine, alcohol, or naphtha. If the etching is not deep enough, an ink roller, such as is used on printing presses, may be passed over the surface and a coating of ink put on. This will prevent any acid action upon the surface thus protected, and the corroding solution may be reapplied until the etching is sufficiently deep. If successive etchings are necessary, the plate should be rinsed and warmed after each removal of

the corroding solution, and more ink applied before another lot of fresh corroder is put to work.

In regular work, where large numbers of zinc etchings are made, dragon's blood is used to protect the surface instead of printer's ink, but for occasional work ink is good enough. Nitric and sulphuric acids may be used for etching, and the effect of the composition described above depends upon the chlorine and sulphuric acid set free by the combination of the two salts.

Etching on glass may be done as easily as etching upon steel or other metals. To do this exactly the same preparations are made, then a mixture of sulphuric acid and a powdered fluorspar is spread upon the surface to be etched. Another and cleaner way, although it takes longer, is to put the acid and powdered spar in a shallow lead dish and invert over it the article to be etched. The subject thus serving as a cover to the acid dish, it is exposed to the fumes which arise and which are almost as corrosive as the mixture itself. Etching is always unsatisfactory unless the wax is evenly spread, cleanly cut out, and everything very neatly done.

Etching on Zinc.—Dissolve 2 parts of crystallized cupric sulphate (blue vitriol) and 3 of cupric chloride in 64 of distilled water and add to the solution 8 parts of hydrochloric acid of 1.1 specific gravity. This fluid has a slightly bluish color and sheet-zinc previously scoured bright with dilute hydrochloric acid and sand instantly acquires, on being dipped into it, a very deep velvety black color. By instantly withdrawing the sheet-zinc thus treated from the fluid and immediately rinsing it off in abundance of clean water and then drying, the black coating adheres very firmly, so that it is probable that this mode of etching may answer in many cases as a sort of paint, especially for zinc intended for roofing. For *etching zinc in relief* it is only necessary to draw the lines, letters, etc., upon the zinc with the above-described fluid and, after drying, place the zinc for 1 to 3 hours, according to requirement, in dilute nitric acid (1 part acid to 8 water). By this means the zinc is eaten away while the lines, letters, etc., remain in relief.

Etching Solution for Brass.—Prepare a mixture of 8 parts of nitric acid of specific gravity 1.40 and 80 parts of water; further-

more dissolve 3 parts of potassium chlorate in 50 of water. The two fluids are mixed and used for etching. Ordinary etching ground is used for covering.

Glyphogéne or Etching Fluid for Steel.—This etching fluid consists of the preparatory corroding solution, the rinsing water and the actual corroding solution. The preparatory corroding solution consists of water, 95 parts; chemically pure nitric acid, 5 parts, and some spirits of wine, and is allowed to act for a few minutes only. The articles treated with the preparatory corroding solution are then rinsed off with the rinsing water, consisting of distilled water containing ⅓ of its volume of spirits of wine, and quickly dried. The actual corroding solution is composed of distilled water, 30 parts; spirits of wine, 15; chemically pure nitric acid, 6, and crystallized nitrate of silver, ½. A layer 0.59 inch deep is poured upon the plate.

Etching without Etching-ground.—A method of employing the galvanic precipitation of metals for the production of ornamentation either sunk or in relief is given by Millvard and executed as follows: In order to produce sunk figures or drawings the latter are first laid or printed upon the metallic surface. A very thin layer of gold, silver or copper is then galvanically precipitated in the ordinary manner. The precipitated metal deposits itself upon all parts of the surface except those covered by the drawing. The surface of the metal is now cleansed from the material with which the drawing has been executed and is then connected with the negative pole of a galvanic battery, whereby a solution is used which acts only upon the metal of the original plate, so that all the places previously covered by the ground are dissolved or sunk. Instead of using a galvanic battery the metallic surface may be simply dipped into a solution of an acid which only attacks the bare places of the surface, but not the metal deposited upon it. The sunk drawing may on various places be provided with relief lines crossing each other, so that it acquires the appearance of cross-hatching. This is effected by drawing such lines with a brush dipped in varnish before the plate, after being cleansed from the protecting cover, is acted upon by the galvanic battery or the above-mentioned

chemical agents. Another method of producing sunk drawings is as follows: The entire surface is first covered with a metallic layer in the above-described manner. The whole is then coated with a varnish and after executing the drawing in the varnish the surface is exposed to the action of the negative pole of a galvanic battery or dipped into a suitable solution of an acid salt, whereby the metal, exposed by cutting through the varnish, is dissolved and removed, thus producing a sunk drawing.

Figures in Relief are Produced as follows: A coating of any kind of metal is first deposited in the above-mentioned manner upon the surface to be ornamented. The figure desired in relief is then drawn or printed upon the deposited metal. The plate is then connected with the negative pole of a galvanic battery or dipped into a solution of an acid salt, whereby all the bare portions of the deposited metal are dissolved and removed, while the lines of the intended figure remain standing out in relief. According to another method the entire surface is coated with varnish and the drawing scratched into the latter. The places thus bared from varnish receive a galvanoplastic coating of any kind of metal, after which all the remaining varnish is removed from the plate. The latter is then exposed to the action of the negative pole of a galvanic battery or treated with a fluid which attacks the metal of the original surface, but not the deposited metal.

For copper printing plates it is especially recommended to cut with a fine, hard needle or a diamond through the layer of gold on the places which are to be etched and then to etch with ferric chloride. The lines may be considerably finer as when the plate is covered with an etching ground, since the layer of gold can be cut through very sharp and does not peal off. By giving the copper plate a thin coat of iron and scratching in the drawing, the latter can be etched with argentammonium sulphate without attacking the iron coating. According to Prof. Husnik, a solution of corrosive sublimate is compounded with a concentrated solution of ammonium nitrate and sufficient caustic ammonia added to redissolve the precipitate at first formed. This corroding substance also exerts no etching effect upon iron. Copper and brass plates

treated in this manner show clear drawings of the amalgam which has been formed. By dissolving the iron and treating the plates with a suitable coloring matter, dark drawings upon a yellow or copper-colored ground are obtained. By applying to etched copper plates, before dissolving the iron coating, silver or gold amalgam, drawings in gold or silver are obtained by the subsequent removal of the iron coating and heating the plate in the open air so that the mercury oxidizes.

Metallography (*Method for Producing Drawings of all Kinds in Relief upon Metal*) *According to Zach.*—The surface of a zinc or steel plate is finally ground and polished, then covered with a ground consisting of white wax, 2 parts; mastic, 2; asphalt, 1; and colophony, ½, and smoked with a wax-torch until it has a lustre. Upon this ground the drawing is then executed with a graver. The plate is then surrounded with a rim of wax and etched 15 to 20 minutes with dilute nitric acid. It is then washed with water, and, after covering the fine lines, if necessary, with asphalt dissolved in oil of turpentine, etching is continued for 15 to 20 minutes more. The ground is then dissolved with oil of turpentine and the plate cleansed. In this manner a sunk drawing is obtained, which, however, must have such a depth that the castings to be made from it afterwards appear sufficiently in relief to allow of their being printed from, in a printing-press. To obtain from this matrix a patrice, *i. e.*, a drawing in relief suitable for printing, a readily fusible metal consisting of bismuth, 7 parts; lead, 4; and tin, 4, is melted. The plate with the deeply etched drawing is placed in a heated mould and the alloy poured over it vertically. The drawing lies afterwards in relief upon the casting without injury having been done to the original.

XI.

ELECTRO-PLATING, BRASSING, COPPERING, GALVANIZING, GILDING, NICKELLING, SILVERING, TINNING, ETC.

[For Electro-plating, etc., of Wire, see that head.]

In all branches of the electro-deposition of one metal upon another several preliminary conditions have to be complied with in order that the deposition may take place uniformly and adhere firmly. The articles must be absolutely free from grease, and, furthermore, their surfaces must be purely metallic. This is effected by mechanical treatment in conjunction with chemical cleaning. The mechanical treatment varies according to the condition of the surfaces of the articles and the demands made on the galvanic deposition. Rough castings to be galvanically coated must first be thoroughly scratch-brushed with pumice-stone, except where, as in the case of copper and its alloys, dipping is substituted for this process. When the rough surface of a casting is coated with another metal the deposition shows the same roughness as the base; hence the articles must be ground or polished in order to obtain depositions with lustrous surfaces. Grinding is almost exclusively effected upon wooden disks covered with leather; emery of various degrees of fineness is glued upon the leather, and, during the grinding, a mixture of emery and tallow or oil is from time to time applied to the articles. When grinding is finished the articles are brushed upon circular brush-disks of bristles or fibres to remove the last fine scratches; the direction of brushing is at a right-angle to the direction of the last grinding, and the brushes are also fed with a mixture of tallow and emery. Only articles of iron and steel are, as a rule, ground, while the softer metals, copper, zinc, etc., are simply brushed and then polished. Polishing is effected by holding the articles against rapidly revolving disks of cloth or felt, which are secured to the shaft of the polishing machine. According to the fineness of the polishing desired, the polishing

disks are fed with various polishing agents, a mixture of Vienna lime and colcothar being mostly used. Grinding disks should make from 1,200 to 1,600 revolutions per minute, and polishing disks from 2,000 to 2,400 revolutions.

The depositions are polished upon similar disks of felt or cloth; silver and gold depositions, however, are burnished with the burnisher and burnishing-stone.

Many depositions have to be scratch-brushed during the galvanic operation in order to get them dense and thick. This is done with fine brass-wire brushes, but for white and hard metal fine steel-wire brushes are used. Scratch-brushing is never done dry, water, decoction of soap-root, beer yeast, etc., being used in connection with it.

The chemical cleaning consists in the removal of grease and dirt and of non-metallic layers upon the surface (scales, rust, etc.).

Freeing from Grease is effected by boiling the articles in caustic lyes (soda or potash lye), which should be followed by brushing or rubbing with pulverized freshly-burnt lime free from sand. Articles which will not stand heating are freed from grease with benzine.

Dipping.—The choice of the fluids for the removal of non-metallic layers depends on the nature of the metals to be dipped. Iron and steel are generally dipped in dilute sulphuric acid, 1 part by weight of sulphuric acid of 66° Bé. to 15 to 20 water; hydrochloric acid may be substituted for the sulphuric acid.

Copper, brass, tombac and bronze are made bright by dipping in compound acids. The operation is as follows: The articles are first dipped in dilute sulphuric acid to remove tarnish, and then in a mixture of 100 parts by weight of nitric acid of 36° Bé., 50 of sulphuric acid of 66° Bé., 1 of soot and 1 of common salt. As soon as the articles show a bright appearance they are quickly rinsed in a large quantity of water which must be frequently changed.

When copper alloys are not to be further worked after dipping, it is generally desirable that they come from the pickle with a certain lustre. To attain this the dipping is executed in two operations, the articles being first made bright in a preliminary pickle

and then dipped into another pickle to give them lustre. The preliminary pickle consists of nitric acid of 36° Bé., 200 parts by weight; common salt, 1; soot, 1.

The pickle for bright lustre is composed of nitric acid of 40° Bé., 75 parts by weight; sulphuric acid of 66° Bé., 100, and common salt, 1. The articles having been made bright in the preliminary pickle, are rinsed off in a large quantity of water, then drawn through hot water so that they dry quickly, and, when dry, dipped into the pickle for a bright lustre; drying is absolutely necessary, the lustre obtained being the more beautiful the freer the pickle is from water.

For a *dead lustre* the brass is dipped in a mixture of 3 parts of nitric acid containing 1 part of zinc in solution, with 8 parts of pure strong nitric acid and 8 parts of boiling sulphuric acid. The strong effervescence which first takes place soon ceases and the brass when taken out presents a dead brown or gray appearance. It acquires lustre by being drawn through strong nitric acid. The following mixture is also recommended: Nitric acid of 36° Bé., 200 parts; sulphuric acid, 100; common salt, 1; sulphate of zinc, 1 to 5. This mixture is used cold.

The following mixture is suitable for the production of a dull-grained surface upon brass: Mix 1 volume of saturated solution of bichromate of potash and 2 of the strongest hydrochloric acid; place the articles in this mixture for a few hours, then drain them through the above-mentioned pickle for bright lustre, and finally rinse them in much water.

German Silver is first dipped in a mixture of nitric acid, 1 part, and water, 10 parts, and then in a mixture of nitric acid and sulphuric acid each 1 part.

Silver is dipped in dilute sulphuric acid, *zinc* also in dilute sulphuric acid or in hydrochloric acid, and *tin* in hydrochloric acid.

In dipping with acids injurious fumes are produced, so that it is prudent to operate in the open air or under a good chimney-hood with a movable glass sash.

Articles which are soldered with soft solder, or contain iron, be-

come black in nitric acid, and hence such places must be made bright again with the scratch-brush.

The articles having been dipped and freed from grease are examined as to whether they are entirely free from grease by immersing them in water; when entirely free from grease they become uniformly wet. If, however, lines and spots appear, the articles are not thoroughly clean and must be again boiled in caustic lye, or, still better, brushed with a mixture of 2 parts whiting and 1 part freshly-slaked lime stirred with water to a thick paste. A scarcely perceptible tarnish (a layer of oxide) being readily formed upon articles freed from grease by dipping, it is recommended to draw them, shortly before suspending them in the baths, through a solution which dissolves the tarnish. For iron such solution consists of dilute sulphuric acid (1 acid to 25 water), and for copper, brass, tombac, bronze and German silver of a solution of cyanide of potassium (1 part of 60 per cent. cyanide of potassium to 20 of water). The articles are then thoroughly rinsed and without delay brought into the bath.

The water used for the preparation of the galvanic baths should be as pure as possible, distilled or filtered rain-water being best for the purpose. Care should be taken to use pure chemicals, as the bad results from baths composed of unsuitable materials are frequently due to impure chemicals. Moreover, the baths must not be too poor in metal nor too concentrated; in the first case the depositions form too slowly and in the latter the salts separate in crystals enveloping the anodes and interrupting thereby the conduction of the current, while by the separation of small crystals upon the articles holes may readily be formed in the deposition. The temperature of baths which work cold should not be below 59° F., a temperature of 64.5° to 68° F. being best. Dust must be kept away from the baths as much as possible, as by depositing upon the articles it might disturb the coherence of the deposition; should a layer of dust be observed upon the baths they must be filtered or the dust removed by drawing a broad strip of blotting-paper over the surface.

There are two kinds of batteries used for electro-deposition:

those which act under the action of physical agents, but these, on account of their feeble intensity, are rarely used; others act under the influence of chemical reactions, of decompositions and recompositions, or of greater or less affinities. The varieties of these instruments are, at the present time, very numerous. But the best battery is that which, under the smallest volume, is the most energetic, constant, regular and economical.

When dynamo-electric machines are not used, Bunsen's battery is the most suitable for the execution of galvanic depositions. Each element is composed of a glass vessel which is half filled with nitric acid at 36° or 40° Bé, and which receives a hollow cylinder of pulverized coke, moulded and cemented at a high temperature by sugar, gum or tar. At the upper part of this cylinder, where it does not dip into the acid, a copper collar is fixed, which may be tightened at will by means of a screw. A copper band or ribbon is fixed to the collar, and may be connected with the zinc of another element. A porous porcelain cell is placed inside the coke cylinder, and contains a dilute solution of sulphuric acid (1 part acid and 9 parts water), into which is put a bar or cylinder of zinc strongly amalgamated or covered with mercury. When a battery of several elements is to be formed the coke of the first element is connected with the zinc of the second, and so on, and the apparatus is completed at one end by coke communicating with the anode, and at the other by a zinc connected with the cathode or object to be electroplated.

A modification of Bunsen's battery, which is preferred by gold and silver electroplaters, is as follows: Each element is composed of an exterior vessel or pot, most generally of stoneware; a cylinder of zinc, covered with mercury, provided with a binding screw or with a copper band, whether for a single element or for the end of a combination of elements in a battery, or to connect the zinc with the carbon of another element; a porous cell of earthenware pipe or porcelain; a cylinder of graphite, made from the residue found in old gas retorts. The graphite is bound by a copper band fixed to it by means of a wire of the same metal, all the binding being afterwards covered with a thick varnish to pro-

tect it from the acid fumes of the battery; notwithstanding the varnish the acid may rise by capillary attraction and corrode the copper band between the carbon and the wire; therefore, binding screws of various shapes and sizes should be used to connect the carbon or zinc by means of ribbons or wires. Use conducting wires of pure copper covered with cotton, silk, india rubber or gutta-percha, and presenting the metal at their extremities in order to effect the connections. Figs. 22, 23 and 24 show the three forms of Bunsen's elements mostly used.

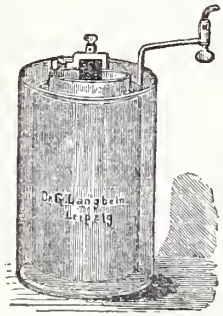


Fig. 22.

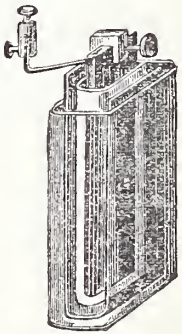


Fig. 23

Fig. 24.

Other batteries used are Daniell's, Grove's, Grenet's, Smee's, Meidinger's, etc., but for a description of these and of dynamo-electric machines the reader is referred to works on this subject.

Batteries must be kept in a place where the temperature does not greatly vary. A frost arrests their action, and great heat increases it too much. A good place for them is a box, and they are put at such a height that they may be easily manipulated. This box should have means of ventilation in such a way that the air coming in at the lower part will escape at the top through a flue and carry away with it the acid fumes constantly disengaged. It is best to keep the batteries in a room different from that where the baths and metals are to be operated upon, as these are easily injured by acid vapors. The galvanic current may be conducted into the

work-room by wires passing through holes in the wall and covered with gutta-percha.

Terms Used in Electrolytic Deposition of Metals.—1. The terms "cathode" and "anode" are synonymous with the positive and negative poles of an electric or galvanic battery.

2. To measure the volume of electricity passed between these points, the term "ampères" is used as the unit, like feet or cubic feet, for measuring in the usual mechanical sense.

3. For expressing the force with which the volume of electricity is propelled, the term "volt" is used as the unit.

4. The resistance opposed to the electricity is measured by "ohms."

5. The work done in the electrical circuit is expressed by "watts," in the same way that in a steam-engine the power developed is expressed by h. p. To put this shortly:

1 ampère × 1 volt = 1 watt.
1 watt × 746 = E. H. P.

These are the electrical terms employed by common consent in all European languages in connection with this science.

CHEMICAL AND ELECTRO-CHEMICAL EQUIVALENTS.

	Specific gravity.	Chemical equivalent.	Electro-chemical equivalent, milligrammes.	Precipitate by 1 ampère in 1 hour, in grammes.
Hydrogen....	1	1	0.01036	0.0375
Aluminium ..	2.6	13.7	0.14250	0.5137
Antimony ...	6.8	122	1.26880	4.5750
Arsenic.....	5.7	75	0.78000	2.8125
Cobalt.....	8.7	29.5	0.30680	1.1062
Copper	8.8	31.8	0.33070	1.1925
Iron.....	7.5	28	0.29120	1.0500
Gold.....	19.2	98.3	1.02230	3.6862
Lead.....	11.3	103.5	1.07640	3.8812
Nickel.....	8.6	29.5	0.30680	1.1062
Platinum	21.2	98.6	1.02540	3.6975
Silver	10.5	108	1.12320	4.0500
Tin.....	7.3	32.7	0.34010	1.2262
Zinc.....	7.2	59	0.61360	2.2125

With the assistance of this table it can be calculated how long a measured surface has to remain in the bath in order to acquire a deposit of determined weight with the most suitable density of current. Suppose the time is to be determined which a square decimeter of surface has to remain in a nickel bath in order to acquire a deposit $\frac{1}{10}$ millimetre thick with a density of current of 0.5 ampère. First calculate the weight of the precipitate by multiplying the surface in square millimetres with the thickness and specific gravity. One square decimetre is equal to 10,000 square millimetres, which, multiplied by $\frac{1}{10}$ millimetre, gives as a product 1,000, which multiplied by the specific gravity of nickel, 8.6, gives 8,600 milligrammes = 8.6 grammes. Hence a deposit $\frac{1}{10}$ milligramme thick upon a surface of 1 square decimetre represents the weight of 8.6 grammes. Since for the regular deposit per square decimetre, a density of current of 0.5 ampère is required, and 1 ampère precipitates, according to the above table, 1.1062 gramme in 1 hour, ½ ampère precipitates 0.5531 gramme of nickel in 1 hour, and, therefore, about 16 hours will be required to precipitate 8.6 grammes.

According to this example the time, for instance, can also be calculated, which one, two or more dozens of knives and forks or spoons which are to have a deposit of silver of a determined weight, must remain in the bath, when the density of current is known. Suppose 50 grammes of silver are to be deposited upon 1 dozen of spoons and the most suitable density of current is 0.2 ampère per square decimetre; if the surface of 1 spoon represents 1.10 square decimetre, the surface of 1 dozen spoons of equal size is 13.2 square decimetres. Hence, they require 13.2×0.2 ampères = 2.64 ampères; now, since 1 ampère precipitates in 1 hour 4.05 grammes of silver, 2.64 ampères precipitate in the same time 10.7 grammes of silver, and with this current the dozen spoons must remain about 4¾ hours in the bath to deposit 50 grammes of silver upon this surface.

Preparation of Zinc for Batteries.—Melt the zinc and then add tin and mercury; next pour the melted mass in moulds and heat until a portion of the mercury appears upon the surface. The

pieces while still hot are finally subjected to the action of a weak acid solution.

Aluminium Bath.—Aluminium is one of the most difficult and uncertain of metals to deposit electrolytically. The following receipt is given by Mr. Herman Reinbold, who states that it furnishes excellent results: 50 parts by weight of alum are dissolved in 300 of water, and to this are added 10 parts of aluminium chloride. The solution is heated to 200° F., and when cold 39 parts of cyanide of potassium are added. A feeble current should be used.

Antimony Baths.—Galvanic depositions of antimony are but seldom made use of in the industries, though they are very suitable for the production of contrasts in decorating. Gore discovered the explosive power of depositions of solutions of antimony chloride or of antimony containing hydrochloric acid. According to Gore a bath consisting of tartar emetic 3 ozs., tartaric acid 3 ozs., hydrochloric acid 4¼ ozs. and water 1 quart, yields a gray, crystalline deposition of antimony. This bath requires a current of about 3 volts. The deposition possesses the property of exploding when scratched with a hard object.

A lustrous non-explosive deposition of antimony is obtained by boiling 4.4 ozs. of carbonate of potash, 2.11 ozs. of pulverized antimony sulphide and 1 quart of water, for one hour, replacing the water lost by evaporation and filtering. Use the bath boiling hot, employing a piece of antimony as anode. The separated antimony has the color of polished cast-iron, and takes a high polish.

Arsenic Baths.—Depositions of arsenic are frequently used for decorative purposes, for instance, to color gray the dead background of brassed lamp-legs, cans, etc., while the prominent portions are bright brass. A good arsenic bath is as follows: Prepare by boiling for half an hour and filtering a solution of sodium arsenate 1¾ ozs., potassium cyanide 0.88 oz., and water 1 quart. A good deposition of arsenic is obtained with a strong current and having the bath at a temperature of 176° F. Use a platinum-sheet or a carbon plate from natural gas-coal as anode.

Another Bath is composed as follows: Pulverized arsenious acid, 1.75 ozs.; crystallized sodium pyrophosphate, 0.7 oz.; 98 per cent. potassium cyanide, 1.75 ozs.; water, 1 quart. Dissolve the sodium pyrophosphate and the potassium cyanide in the cold water, then add, with constant stirring, the arsenious acid, and heat until the latter is dissolved. The bath is used warm and requires a strong current of at least 4 volts. A platinum-sheet or carbon-plate is used as anode. Large baths, which are preferably used cold, must be more concentrated and require a stronger current than the hot baths.

Brass Baths.—A good brass bath is composed as follows: Carbonate of soda, 10½ ozs.; bisulphate of soda, 7 ozs.; neutral acetate of copper, 4¼ ozs.; chloride of zinc, 4¼ ozs.; 98 per cent. potassium cyanide, 14 ozs.; arsenious acid, 30¾ grains; water, 10 quarts. Dissolve the carbonate of soda in 5 quarts of the water, and then add gradually the bisulphate of carbon. Now stir together the acetate of copper and chloride of zinc with 2 quarts of the water, and slowly, and with constant stirring, pour the mixture into the solution of the soda salts. Next add the solution of the potassium cyanide in 3 quarts of the water, then the arsenious acid, and boil the whole for a few hours, replacing the water lost by evaporation. The solution when cold is filtered.

Brass-bath from Cupric Sulphate and Zinc Sulphate.—Dissolve 5¼ ozs. each of cupric and zinc sulphate in 5 quarts of warm water, and mix the solution with one of 15¾ ozs. of carbonate of soda in 5 quarts of water. Allow the precipitate of carbonate of copper and carbonate of zinc, which is formed, to settle for 12 hours, and then pour off the supernatant fluid. Now add to the precipitate enough water to bring the volume up to 8 quarts; dissolve in it 10½ ozs. of carbonate of soda and 7 ozs. of bisulphate of soda, and finally add a solution of 8¾ ozs. of 98 per cent. potassium cyanide in 2 quarts of cold water, which renders the fluid clear. Before boiling, add 30¾ grains of arsenious acid.

Brass-bath for Zinc.—Dissolve 9¾ ozs. of crystallized bisulphate of soda and 14 ozs. of 70 per cent. potassium cyanide in 8 quarts of water, and add to this solution one of 4¾ ozs. each of

neutral acetate of copper and crystallized chloride of zinc, 5½ ozs. of aqua ammonia, and 2 quarts of water.

Brass-bath for Cast-iron, Wrought-iron and Steel. — Dissolve 35¼ ozs. of crystallized carbonate of soda, 7 ozs. of crystallized bisulphate of soda, 13¼ ozs. of 98 per cent. potassium cyanide in 8 quarts of water; then add, with constant stirring, a solution of melted chloride of zinc 3½ ozs., neutral acetate of copper 4¼ ozs., in 2 quarts of water; boil and filter.

Solution for Transferring any Copper-zinc Alloy serving as Anode. —Bisulphate of soda, 14¾ ozs.; crystallized sal-ammoniac, 9½ ozs.; 98 per cent. potassium cyanide, 2½ ozs.; water, 10 quarts.

The color of the brass deposits depends on the proportional quantity in which copper and zinc are present. A strong current precipitates more zinc, and a weaker one more copper; the deposit being more greenish in the first case, and more reddish in the latter. Hence the necessity arises of regulating the current so that both metals are precipitated in a proportion required for the desired color of the deposit. Formerly the color was obtained by suspending copper and zinc anodes in the bath, and allowing the copper anodes to dip in deeper than the zinc anodes for the production of reddish brass, and the reverse for greenish brass. But at the present time the different colors are produced in one bath with brass anodes, by diminishing or increasing the strength of the current by the current-regulator, which renders the entire process more simple and more assured.

Annealed sheets of brass, with as large a surface as possible, are used as anodes. To increase the metallic content of the bath it is best to use a solution of cyanide of copper and cyanide of zinc in potassium cyanide, adding at the same time some neutral bisulphate of soda, while a thinly fluid paste of cyanide of copper and cyanide of zinc is employed for the removal of an excess of potassium cyanide. The formation of slime on the anodes is treated in the same manner as given for copper baths, which see.

Brass baths showing more than any other baths the peculiarity of precipitating in an irregular manner, when freshly prepared, it is absolutely necessary to thoroughly boil them. If for any reason

this cannot be done, they must for some time be thoroughly worked through with the current before a regular deposit of a uniform color can be obtained. For this purpose as many anodes as possible are suspended in the bath, while a few sheets of brass, zinc or iron are also suspended to the negative pole. A sufficiently strong current, to cause a vigorous development of hydrogen on the cathodes, is then conducted through the bath. A test is from time to time made, to see whether the bath works in a regular manner, and when this is the case the sheets are removed from the negative pole and the operation is commenced.

According to their composition brass baths require a tension of current of 3 to 4 volts, and an intensity of 0.5 to 0.6 ampère per 15½ square inches.

Cobalt Baths.—Nickel being cheaper than cobalt and its color somewhat whiter, electro-plating with this metal is but little practised. On account of its greater solubility in dilute sulphuric acid it is, however, under all circumstances to be preferred for coating valuable copper-plates for printing. Gaiffe recommends for this purpose a solution of 1 part of chloride of cobalt in 10 of water. The solution is to be neutralized with aqua ammonia, and the plates are to be electro-plated with the use of a moderate current.

Cobalt precipitated from a chloride solution does not yield, however, a hard coating, and hence the following bath is recommended for the purpose: Double sulphate of cobalt and ammonium, 21 ozs.; cobaltous carbonate, 0.8 oz.; crystallized boric acid, 10½ ozs.; water, 10 quarts. This bath requires a current of 2.5 to 2.75 volts.

Warren has recently described a solution of cobalt which can be decomposed in a simple cell apparatus, and for this reason would seem to be suitable for electro-plating small articles *en masse*. For the preparation of the bath dissolve 3½ ozs. of chloride of cobalt in as little water as possible, and compound the solution with a concentrated solution of Rochelle salt until the voluminous precipitate at first formed is almost entirely redissolved, and filter. Bring the bath into a vessel and place the latter in a clay cell, filled with concentrated solution of sal-ammoniac or common salt, and

containing a zinc cylinder. Connect the articles to be electro-plated by a copper wire to the zinc, and allow the articles to dip in the cobalt solution.

Electro-plating with Cobalt by contact.—While nickelling by touching with zinc yields only incomplete results, the electro-plating with cobalt of copper and brass articles succeeds very well with the use of the following bath: Crystallized cobalt sulphate, 0.35 oz.; crystallized sal-ammoniac, 0.7 oz.; water, 1 quart. Heat the bath to between 104° and 122° F., and immerse the previously cleansed and pickled articles in the bath, bringing them in contact with a bright zinc surface; for small articles a zinc sieve may be used. In 3 or 4 minutes the coating is thick enough to bear vigorous polishing.

Copper Baths.—The composition of these baths depends on the purpose for which they are to serve, and in the following the most approved baths are mentioned, with the exception of the acid copper bath, which is used for plastic deposits of copper.

In most cases the more electro-positive metals—zinc, iron, tin, etc.—are to be coppered, either as a preparation for the succeeding process of nickelling, silvering, or gilding, or to protect them against oxidation by a thick deposit of copper. The above-mentioned electro-positive metals, however, decompose the acid copper solutions, and separate from them pulverulent copper, while an equivalent portion of zinc, iron, tin, etc., is dissolved. For this reason such solutions of copper cannot be used for coating these metals, alkaline copper baths being exclusively employed for the purpose, which may be arranged in two groups—into those containing potassium cyanide and into those without it.

Hassauer prepares a copper bath by dissolving 3½ ozs. of copper cyanide in a solution of 17.5 ozs. of 70 per cent. potassium cyanide, in 3 quarts of water, boiling, filtering, and diluting with 7 quarts of water to a 10-quart bath. This bath works very well when heated to between 113° and 122° F., but when used cold requires a very strong current.

Copper Baths for Iron and Steel Articles.—I. *To be Used at an Ordinary Temperature.*—Water, 10 quarts; crystallized bisulphate

of soda, 7 ozs.; crystallized carbonate of soda, 14 ozs.; neutral acetate of copper, 7 ozs.; 75 per cent. potassium cyanide, 7 ozs.; spirit of sal-ammoniac, 4.4 ozs.

II. *To be Used at from 140° to 158° F.*—Water, 10 quarts; crystallized bisulphate of soda, 2¾ ozs.; crystallized carbonate of soda, 7 ozs.; neutral acetate of copper, 7 ozs.; 75 per cent. cyanide of potassium, 9¾ ozs.; spirit of sal-ammoniac, 4 ozs. The baths are best prepared as follows: Dissolve the bisulphate and carbonate of soda in one-half the water, the potassium cyanide in the other half, and mix the copper salt with the spirit of sal-ammoniac; then pour the blue ammoniacal copper solution into the solution of the soda salts, and finally add the potassium cyanide solution; the bath will be clear and colorless. Boiling, though not absolutely necessary, is of advantage, after which the solution is to be filtered.

The following formula is highly recommended: Water, 10 quarts; crystallized carbonate of soda, 8½ ozs.; crystallized bisulphate of soda, 7 ozs.; neutral acetate of copper, 7 ozs.; 98 or 99 per cent. potassium cyanide, 8½ ozs. The bath is prepared as follows: Dissolve in 7 quarts of warm water the carbonate of soda, *gradually* add the bisulphate of soda to prevent violent effervescence, and then add, with vigorous stirring, the acetate of copper in small portions. Dissolve the cyanide of potassium in 3 quarts of cold water, and mix both solutions when the first is cold. By thorough stirring with a clean wooden stick a clear solution is obtained, which is best boiled for half an hour, and then filtered.

For small *zinc articles* which are to be coppered in a sieve, the bath is warmed and a little more potassium cyanide added.

Instead of acetate of copper cupric sulphate (blue vitriol) may be used for preparing the baths, the following formula being especially suitable for the purpose: Dissolve 10½ ozs. of cupric sulphate and 14 ozs. of carbonate of soda, each by itself, in hot water, and mix both solutions; allow the precipitate of carbonate of copper which is formed to settle and pour off the clear supernatant fluid. To the precipitate add 7 quarts of water, then gradually 8½ ozs. of carbonate of soda and 7 ozs. of bisulphate of soda, and mix this solu-

tion with one of 8½ ozs. of 98 per cent. potassium cyanide in 3 quarts of water. After mixing, the discoloration of the fluid takes place rapidly, when it is boiled and filtered.

Annealed sheets of pure copper with as large a surface as possible serve as anodes. They become gradually covered with a green slime, which must from time to time be removed by scouring with sand. When a very strong and rapid formation of slime takes place and the bath becomes bluish, potassium cyanide is wanting and must be added. Too large an excess of potassium cyanide causes strong development of hydrogen and no deposition, or only a very slight one, takes place, which besides has the tendency to peel off. Such excess can be readily removed by the addition of cyanide of copper, stirred with water to a thinly fluid paste. As the anodes are not able to keep the content of copper in the bath constant, there being not as much copper dissolved from them as is precipitated, the content of metal in the bath must be increased, when it commences to work slowly, by the addition of solution of cyanide of copper in potassium cyanide; it is also advisable to add at the same time some neutral bisulphate of soda.

The deposit of copper is thoroughly brushed with a soft brass scratch-brush, the article is then returned to the bath, and again scratch-brushed, this being repeated until the deposit is of sufficient thickness. The coppered articles are then immersed in hot water, dried in saw-dust, and finally polished dry with Vienna lime upon fine flannel disks. The polished articles are lastly coated with a colorless lacquer to prevent oxidation in the air.

Copper Bath without Potassium Cyanide.—Dissolve 52¾ ozs. of potassium sodium tartrate (Rochelle salts), 10½ ozs. of cupric sulphate, 28 ozs. of caustic soda in 10 quarts of water.

The Elmore Process of Electro-depositing Copper for Tubes and Wire Bars.—A revolving, cylindrical mandril of iron is placed in an electrolytic vessel containing solution of cupric sulphate. Around the mandril are arranged bars of copper, which communicate with the positive pole of a dynamo whilst the mandril communicates with the negative pole. The copper deposits upon the bottom, and when the deposit has acquired sufficient thickness the

tube is withdrawn, which thus has been finished without soldering. To impart to the deposited copper tenacity and ductility its surface is rubbed with a polishing-stone. The agate used as a polishing-stone presses lightly upon the surface of the copper, being in continual operation from one end of the revolving mandril to the other. The velocity of both is so regulated that the entire surface of the deposit is rubbed by the polishing-stone, and that the thin layers successively deposited are suitably polished and acquire the necessary mechanical properties. The impurities of the copper thus electrolyzed and purified fall to the bottom of the electrolytical vessel, from whence they are removed, washed, dried, and melted, to be finally treated for the recovery of gold and silver.

By the nature of the above-described process the copper is necessarily and unavoidably pure; and is, therefore, especially adapted for cable and other electrical purposes. Special machinery has been arranged so that an electro-burnished tube produced by the above-mentioned method may be cut spirally into a square wire, which can then be drawn down in the usual manner to any required diameter. The wire being drawn directly from the electro-burnished tube obviates entirely the necessity for melting, and thus constitutes altogether a new departure in the manufacture of pure copper wire. Some of the tests to which it has been subjected are very interesting. Two large coils of the new wire were taken, the wire of the first having a diameter of 0.113 inch (about 12 Birmingham wire gauge), and the second a diameter of 0.05 inch (about 18 B. W. G.), both being extremely hard drawn. In order, however, to be perfectly satisfied that the practical limit of hardness had been reached, the larger wire was drawn through 13 holes in a draw-plate (the last hole being of agate) without annealing, until the diameter of the wire was reduced to 0.057 inch. Its hardness may be judged of by the fact that the breaking-strain was 29 tons per square inch, with an elongation of only ¾ per cent. The No. 18 B. W. G. wire had a breaking-strain of nearly 29 tons per square inch, with an elongation of only ⅜ per cent. When these wires were annealed they showed an elongation of 25 to 33 per cent. before breaking.

Dr. Matthiessen found that the purer the metal was obtained the greater was the variation of its electrical resistance with corresponding variations of temperature, and gave the general law as $Rt = Ro (1 + at + b t^2)$ where Ro is the resistance of the metal or alloy at the temperature of O° C., and Rt the resistance of any temperature t degrees C. above O°. He found that for most pure metals the value of *a* was 0.003824 t, and *b* 0.00000126 t^2 with the sign + between them. The experiments carried out on the new wire are confirmatory of its great purity, as these coefficients are found to be distinctly higher, the expression for it being $Rt = Ro (1 + 0.00411158\ t + 0.000003077\ t^2)$.

The results of the conductivity tests are given in the first table. The conducting power of the hardest wire is so high that, with a breaking strain of 29 tons per square inch, it has a conductivity about 2½ per cent. higher than that of soft annealed wire of the best quality hitherto obtained commercially (say 98 per cent.). When the new wire is annealed it has a conducting power 4½ per cent. above the best commercial copper.

Diameter.	Gauge (approximate) B. W. G.	Conductivity of annealed wire in terms of standard for annealed copper.	Conductivity of annealed wire in terms of standard for hard copper.
in.			
0.113	12	102 33	104.39
0.057	17	102.35	104.41
0.049	18	102 45	104.51
Mean.....	... .	102.38	104.44

The following mechanical tests have been made on the wire, each result being the mean of three experiments:

Diameter.	Weight per statute mile.	Breaking strain.		Elongation.	Number of twists in 3 inches.
		Observed.	Per sq. in.		
In.	Lb.	Lb.	Tons.	Per cent.	
0.113	205.0	612	27.4	2	31
0.082	110.0	375	31.2	1⅝	42
0.057	52.8	166	28.7	¾	not taken.
0.05	40.8	127	28.4	⅜	47

The wire was also tested as follows: It was wrapped six times around its own circumference, as in making a "bell-hanger's joint." It was then unwrapped, wrapped again, and so on until the wire broke. The results were:

Diameter. In.	Specimen. No.	Wrapping and Unwrapping.							
		on	off	on	off	on	off	on	off
0.113	1	6	6	6	6	6	6	..	..
	2	6	6	6	6	6	6	6	..
	3	6	6	6	6	6	6	6	..
0.05	1	6	6	6	6	6	3	..	..
	2	6	6	6	6	6	6	6	4
	3	6	6	6	6	6	6	6	6

It will thus be seen that the hard wire is admirably adapted for over-head telegraph wires, possessing the two requisites of great strength and high conductivity. The efficiency of dynamo machines and electrical instruments can be increased, because a greater number of "ampère-turns" can be got within a given space. The copper tape or riband used so extensively for lightning conductors can be cut direct from the tube, of any length and sectional area, by the special machinery before mentioned. It would take up too much space to dilate upon the enormous demands for pure copper that must arise, due to the development of the industrial application of electricity.

To get a Copper Deposit on Wax.—Coat the wax with black-lead; brush the wax over with alcohol, and follow with black-lead plumbago, rubbing with a soft brush. The deposit is made from a saturated solution of sulphate of copper (blue vitriol) in water; the solution should stand for 24 hours, and be stirred occasionally before using. A copper wire is melted into the wax and the black-lead well worked with the brush over it, so as to make an electric connection between the wire and the wax. The copper plate placed in the solution from which the copper is dissolved to keep up the strength of the solution, is attached to the carbon or copper pole of the battery and the wax to the zinc pole.

Brush-coppering for Iron and Steel.—This process can be rec-

ommended for its simplicity and general applicability. The utensils required are two vessels of sufficient size, each provided with a brush preferably so wide that the entire surface of the article to be treated can be coated with one application. One of the vessels contains a strongly saturated solution of caustic soda, and the other a strongly saturated solution of cupric sulphate (blue vitriol) of the best quality.

For coppering, the well-cleansed article is first uniformly coated with a brush full of the caustic soda solution, and then also with a brushful of the copper solution. A quite thick film of copper is immediately firmly deposited upon the article. Care must be had not to take the brush too full, and not to touch the places once gone over the second time, as otherwise the layer of copper does not adhere firmly. The coppering thus produced is so strong and durable that, without fear of injury, the articles may afterwards be scratch-brushed, gilded and silvered, and also colored brown or steel-blue.

For coloring, the following directions are given: For *brown*, dissolve 6.77 drachms of calcium monosulphide and 1 oz. 6 drachms of powdered sal-ammoniac in 10 quarts of water. Small articles are dipped into this solution and large ones brushed over with it. After dipping, the articles are to be thoroughly scratch-brushed, as they show various colors when they come from the bath, and acquire a uniform tone only by scratch-brushing.

For Dark-steel Blue.—Dissolve from 12 drachms to 1 oz. of potassium sulphide and the same quantity of common salt in 10 quarts of water. The bath is used in the same manner as for brown.

This process can be especially recommended for articles which are to be decorated in several colors. By only partially gilding or entirely silvering such articles, very beautiful effects can be produced by the use of the above-described method, which, with some experience, is less difficult to execute than coppering by the galvanic current or by immersion.

How to Copper Iron.—Iron can be coppered by dipping it into melted copper, the surface of which is protected by a melted layer

of cryolite and phosphoric acid; the articles to be thus treated being heated to the same temperature as the melted copper. *Another process* consists in dipping the articles into a melted mixture of 1 part of chloride or fluoride of copper, 5 or 6 parts of cryolite, and a little chloride of barium. If the article, when immersed, is connected with the negative pole of a battery, the process is hastened. *A third method* consists in dipping the articles in a solution of oxalate of copper and bi-carbonate of soda, dissolved in 10 or 15 parts of water, acidified with organic acid.

To Copper Iron and Steel.—First free the objects of cast-iron, steel or wrought-iron from rust, and then brush them thoroughly with a brush of hard bristles dipped in pulverized tartar saturated with cupric sulphate (blue vitriol). The articles thus treated will be coated with a thin, uniform and firmly adhering layer of copper.

To Copper Cast-iron.—To provide cast-iron articles with a beautiful and durable coating of copper proceed as follows: Scour the article with a pickle consisting of 50 parts of hydrochloric acid of 15° Bé. and 1 part of nitrate of copper. Then rub them with a woollen rag or a soft brush dipped in a solution of 10 parts of nitrate of copper and a like quantity of cupric chloride in 80 parts of nitric acid of 15° Bé. After a few seconds rinse the articles in clean water and polish them with a dry woollen rag. This rubbing and subsequent polishing is repeated until the layer of copper is of the desired thickness. In this manner ground or rough objects can be entirely or partially coppered, the process being recommendable on account of its simplicity, cheapness and the durability of the coppering. To give articles thus coppered the appearance of antique bronze, touch them up with a solution of 4 parts of sal-ammoniac, 1 part of oxalic acid and 1 part of acetic acid in 30 parts of water, the operation being repeated until the object has acquired the desired color.

To Coat Iron Articles with Copper, Brass or Bronze.—W. Tytherbigh, of Birmingham, England, proceeds as follows: The sheets are first pickled and then uniformly covered with a layer of brass-filings upon which borax is scattered. The sheets thus prepared are

next brought into a furnace heated to the proper degree. The union of the two metals takes place by the fusion of the brass, the time required for the process being only about ten seconds. The union is very complete, so that the sheet can at will be rolled, stamped, annealed, etc., without fear of a separation of the two metals, and the brass can only be removed from the iron by filing. This process is especially suitable for ship-sheathing. For coating small cast or wrought-iron articles with copper, brass, bronze or a similar alloy another method is employed. The metal or alloy with which the iron is to be coated is melted with an addition of borax in suitable iron or clay vessels, the thoroughly cleansed articles are then dipped into the bath and are moved to and fro so that they acquire the heat of the metal and become coated with it. They are then taken out and allowed to cool upon a grate, they being moved about until the coating congeals. Larger articles are heated before placing them in the melted metal.

To Coat Tin, Cast-iron or Zinc with Copper.—The bath can be used cold as well as warm, and consists of sodium sulphide, 10.58 ozs.; 75 per cent. cyanide of potash, 17.63 ozs.; acetate of copper, 12.34 ozs.; ammonia, 7.05 ozs.; and water, 55 lbs. A bath for smaller articles of zinc, which are generally coppered at a boiling heat in a strainer, consists of sodium sulphide, 3.52 ozs.; cyanide of potash, 24.69 ozs.; acetate of copper, 15.87 ozs.; ammonia, 5.29 ozs.; and water, 44 to 55 lbs. The acetate of copper is dissolved by itself in 5 quarts of water and, after mixing it with the ammonia, added to the other solution. When cyanide of potash of unknown content is used, its solution is added last until the fluid is entirely discolored.

To Copper Zinc Plates.—To coat a zinc plate with a hard though very thin layer of copper, dip it into a bath composed of 100 parts of water saturated with cupric chloride (40 cupric chloride and 60 water), 150 parts of ammonia and 3000 of water. For very solid coppering use the above described bath, which has a fine blue color, and add a saturated solution of prussiate of potash in water until the blue color of the first mixture has quite disappeared. This process of coppering is somewhat slower than by

the galvanic way, but yields nearly as solid results. For plates engraved with the graver, or stamped, it is best to use a mixture of prussiate of copper with neutral potassium sulphate, to which is added another mixture of cupric sulphate (blue vitriol) dissolved to saturation in water, and of water saturated with prussiate of potash. After the complete solution of the precipitate and discoloration of the fluid, the bath is ready for use. By now adding to the above-mentioned reagents, sulphate or chloride of zinc, a very good brass bath is obtained which is allowed to act upon the zinc plate by means of a single electric element. Instead of using completely saturated baths one-quarter to one-third of their volume of ordinary water may be added to them. For hard coppering the second bath is the most suitable, it yielding very satisfactory results, and as it is known to contain prussiate of potash there is no danger, provided care be exercised.

Gold-baths.—There are a large number of receipts for gold-baths, and only the most approved will be mentioned in the following. Baths for electro-gilding are used either cold or warm. Warm gold-baths need not to be so rich in gold as cold baths, require less strength of current, and, generally speaking, yield denser depositions of warmer tones. By using pure gold solution, which contains no other metal, the separated gold has the pure yellow color characteristic of fine gold; for a more reddish or more greenish color, *i. e.*, the color of gold alloyed with copper or silver, a bath containing copper or silver besides gold has to be used. Some electro-platers prefer baths prepared with potassium cyanide, others those prepared with potassium ferro-cyanide. The first are considered the most profitable.

It does not pay to dissolve the gold for the baths, since chloride of gold of great purity can be procured from chemical factories. Brown neutral chloride of gold should be asked for, the crystallized, orange-color salt containing too much acid.

The most simple gold-bath consists of neutral chloride of gold, 0.35 oz.; 99 per cent. potassium cyanide, 0.7 oz.; and water, 1 quart. Dissolve the potassium cyanide in one-half of the water and the chloride of gold in the other half; mix both solutions and

boil for half an hour, replacing the water lost by evaporation. The color of the deposition of gold yielded by this bath is, however, not so warm as when the following bath is used for cold electro-gilding:

Dissolve 0.24 oz. of neutral chloride of gold in 1 pint of water and add spirit of sal-ammoniac as long as a yellow precipitate of fulminating gold is formed. Then filter off and wash the precipitate in the filter with distilled water, rinse the residue from the filter into a porcelain dish, and add water until the volume amounts to 1½ pints. Then dissolve in ½ pint of water ½ oz. of 99 per cent. potassium cyanide, add this solution to the first and boil, with constant replacement of the water lost by evaporation, until the fluid shows no odor of ammonia.

One quart of this bath prepared from fulminating gold mixed with 3 quarts of distilled water gives an excellent bath for warm electro-gilding, for which purpose it is to be heated to between 158° and 167° F.

Too large an excess of potassium cyanide in the gold baths must be avoided, it causing a pale color in the gilding.

Another bath suitable for electro-gilding is as follows: Chemically pure sodium phosphate, 2.11 ozs.; neutral sodium sulphide, 0.35 oz.; 99 per cent. potassium cyanide, 0.7 oz.; neutral chloride of gold, 0.7 oz.; and distilled water, 1 quart. The salts are dissolved in the order mentioned, in the cold water. The bath is used at a temperature of from 158° to 167° F. If it is to be used for the direct gilding of iron and steel, only 0.18 to 0.35 oz. of potassium cyanide is taken instead of 0.7 oz.

A formula for a cold bath prepared with potassium ferrocyanide instead of potassium cyanide is as follows: Yellow prussiate of potash, 0.56 oz.; sodium carbonate, 0.56 oz.; fine gold (in the form of chloride of gold or fulminating gold), 0.7 oz.; water, 1 quart. Heat the solution of the yellow prussiate of potash and of the sodium carbonate in the 1 quart of water to boiling, then add the gold salt, and boil for ¼ hour, or with the use of freshly precipitated fulminating gold, until the disappearance of the ammonia odor. When cold the solution is mixed with a quantity of distilled

water corresponding to the quantity of water lost by evaporation, and filtered. This bath gives a good gilding upon all metals, including steel and iron. Suitable strength of current, 3.25 to 3.5 volts.

Many electro-platers prepare the gold baths with the assistance of the electric current. For this purpose prepare a solution of 3.52 ozs. of potassium cyanide (98 to 99 per cent.) per quart of water, and after heating to from 122° to 140° F., conduct the current of two Bunsen elements through two sheets of gold, not too small, which are suspended as electrodes in the potassium cyanide solution. From the sheet of gold connected to the positive pole the gold dissolves off, forming potassium aurocyanide. The action of the current is interrupted when the solution is so far saturated with gold that an article immersed in it and connected to the negative pole instead of the other gold-sheet, is gilded with a beautiful warm tone. By weighing the sheet of gold serving as anode, the amount of gold which has passed into solution is ascertained. A good gold bath prepared according to this method should contain 3.52 ozs. of potassium cyanide and 0.7 oz. of fine gold per quart of water.

As anodes it is best to use sheets of fine gold, which gradually dissolve, and thus convey fresh metal to the bath. The insoluble platinum anodes should only be used in the production of very thin depositions. The color of the gold deposited depends on the content of gold of the bath, its temperature, and the strength of the current. Warm baths rich in gold give with a strong current a brown, pulverulent deposition which, though it becomes bright by scratch-brushing, parts with gold. Hence the use of a current-regulator is of great advantage, since with its assistance various shades of gold color can be obtained in one bath. It may be accepted as a rule that the stronger the current the more reddish and fiery the color will be, and the weaker the current the paler and more greenish the color. Electro-platers of the old school use platinum anodes for the production of the color, allowing them to dip in more or less deep; in the first case the gilding becomes more reddish, since more of the current passes into the bath, and in the latter paler.

Only copper, brass, bronze, and tombac can be directly gilded; other metals must first be coppered or brassed; cheap steel articles are an exception, however; for instance, needles, the eyes of which may be directly gilded. Amalgamating the articles before gilding is unnecessary. The current must not be so strong that a formation of bubbles is perceptible, as otherwise the gold would separate brown and pulverulent; it is best to use a current of such strength only that deposition takes place slowly, a coating of the greatest density being thus obtained. For the production of a thick deposit frequent scratch-brushing of the articles is absolutely necessary, the brush being moistened with decoction of soap-root or solution of tartar. To obtain red gold a copper salt has to be added to the gold bath, it being best to use solution of copper cyanide in potassium cyanide, small portions of which are gradually added until the desired tone of red gold is obtained; a gold bath may also be converted into a red gold bath by suspending a few copper anodes alongside of the gold anodes.

Green gold is obtained by the addition of silver solution, cyanide or chloride of silver dissolved in potassium cyanide; or by suspending a few silver anodes alongside the gold anodes, whereby strict attention must be paid to the careful regulation of the current.

Gilding with a Dead Lustre may be effected by the slow deposit of a large proportion of gold. This gilding is very durable, but dull and earthy in appearance and is costly. Other means of effecting the same purpose are: 1. *By acids*, giving a dead lustre to the metallic surface, previous to gilding, and by the processes indicated in the cleansing operations. This is employed for small articles, or, when gilding by dipping, for brass articles, or large embossed work. 2. *With frosted silver*, by depositing upon the object to be gilt a coat of frosted silver and then gilding in a good bath; this method is expensive, the burnished parts are greenish, and the intermediary coat of silver is more easily blackened by sulphur fumes than gold. 3. *By copper*, by depositing in a solution of sulphate of copper, decomposed by the current, a coat of this metal, which possesses a pink dead lustre. The whole is

rapidly passed through the acid mixture for bright dipping and then gilded in a good bath.

The deposits of gold are frequently further colored in case they have not acquired the right tone in the bath. This is effected by treating them with gilders' wax or brushing with certain mixtures.

Treatment with gilders' wax consists in uniformly coating the gilt articles with the wax and burning it off over a charcoal fire. The articles are then dipped in water, scratch-brushed with wine-vinegar, dried and burnished. (For various compositions of Gilders' Wax see under that head.)

To give the articles a rich appearance they may be coated with a paste of 3 parts alum, 6 parts saltpetre, 3 parts sulphate of zinc, 3 parts of common salt and water, heating until the mixture turns black, washing and scratch-brushing with wine-vinegar.

Gilding by Contact and Dipping, Cold Gilding and Gilding by Adhesion.—The article is first pickled and must not again be touched with the hands. It is then placed in a solution of gold and touched with a rod of zinc or copper, whereby metallic gold is precipitated upon the article; by a shorter or longer contact different colors may be produced. Gold solutions of varying composition are employed for gilding by contact, the following solution being, for instance, used for jewelry. Prepare first a gold solution by dissolving 3.52 ozs. of fine gold in a mixture of 8.81 ozs. of nitric acid and a like quantity of hydrochloric acid in a glass or porcelain vessel, which is allowed to stand a few days in a warm place. To promote dissolution it is best to use the gold in the form of thin sheet or wire, thick pieces dissolving very slowly. The clear gold solution is then gradually mixed with 6.6 lbs. of bicarbonate of potash, whereby it strongly effervesces, and the whole is then poured into an iron kettle containing 20 quarts of boiling water. The articles to be gilded being again pickled with sulphuric acid are then tied together with brass wire, again dipped for a moment in a mixture of nitric and hydrochloric acids, rinsed and then immediately immersed in a mercury solution prepared by dissolving mercury in nitric acid and diluting the solution with water. In case the articles contain much copper they quickly ac-

quire a white color in the mercury solution by becoming coated with a thin layer of mercury. They are then placed in the gold bath and touched with a zinc rod. After remaining in the gold bath for about half a minute they are taken out, rinsed off and dried. The rinsing water, which contains gold, is collected and the gold regained by acidulating the water with hydrochloric acid and pouring into it a solution of ferrous sulphate (copperas), whereby the fluid acquires an inky appearance, but soon again becomes clear. On the bottom of the vessel will then be found a very fine brown powder, which consists of chemically pure gold and can be again used for the preparation of gilding fluid. By sufficiently heating the baths the following formula may also be advantageously used for gilding by touching with a zinc rod:

I. Fine gold (in the form of fulminating gold) 0.56 drachm; 98 per cent. cyanide of potash, 2.82 drachms; water, 1 quart. The bath is prepared by converting 0.56 drachm of fine gold into neutral chloride of gold by dissolving in aqua regia and evaporating; or, 0.67 to 0.7 oz. of neutral chemically pure chloride of gold is dissolved in water, the gold precipitated as fulminating gold with liquid ammonia and washed. It is then dissolved in the water containing the cyanide of potash and heated until the odor of ammonia disappears, the water lost by evaporation being constantly replaced. The temperature of the bath should be about 158° to 167° F. If necessary the amount of cyanide of potash may be increased.

II. Chemically pure crystallized sodium phosphate, 2.11 ozs.; neutral sodium sulphate, 5.64 drachms; cyanide of potash, 1.12 drachms; fine gold (in the form of chloride), 0.56 drachm; distilled water, 1 quart. If this bath is to be used for the direct gilding of steel only 0.56 drachm of cyanide of potash need to be taken. Dissolve at a moderate heat in a porcelain or enamelled iron vessel the sodium phosphate and neutral sodium sulphate, and to the perfectly cold solution add the neutral gold chloride prepared from 0.56 drachm of gold and the cyanide of potash. For use heat the bath to from 158° to 167° F.

III. The following bath yields a good deposit: Fine gold (in the

form of chloride of gold), 1.97 drachms; yellow prussiate of potash, 1 oz.; potash, 1 oz.; common salt, 1 oz.; water, 1 quart. To prepare the bath heat the solution of the yellow prussiate of potash, potash and common salt in the water to the boiling point, add the gold salt and boil ¼ hour. After cooling the solution is compounded with the quantity of distilled water corresponding to that lost by evaporation, and filtered. For use heat the bath to the boiling point.

In the execution of gilding by contact the points of contact must be frequently changed to prevent stains.

For Baths for Gilding by Dipping the following two formula have stood the test. I. Crystallized sodium pyrophosphate, 2.82 ozs.; 12 per cent. prussic acid, 4.51 drachms; crystallized chloride of gold, 1.12 drachms; water, 1 quart. Heat the bath to the boiling point and immerse the pickled objects of copper or its alloys, moving them constantly, until gilded. Iron, steel, tin and zinc are previously coppered, coating the articles with mercury before immersion being entirely superfluous.

All gold baths prepared with sodium pyrophosphate give quick and beautiful results when fresh, but they have the disadvantage of quickly decomposing and can consequently seldom be completely utilized. In this respect the following formula answers much better:

II. Crystallized sodium phosphate, 2.82 drachms; chemically pure caustic potash, 1.69 drachms; chloride of gold, 0.56 drachm; 98 per cent. cyanide of potassium, 9.03 drachms; water, 1 quart. Dissolve the sodium phosphate and caustic potash in ¾ of the water and the cyanide of potash and chloride of gold in the remaining ¼. Heat the solution to the boiling point; the bath can be almost entirely utilized, it not being decomposed by keeping. Should the bath become weak add about 2.82 drachms of cyanide of potash and use it for preparatory boiling until no more separation of gold is obtained. To complete the coating the articles subjected to such preparatory boiling are then dipped for a few seconds in a freshly prepared bath of the composition given above.

The layer of gold formed by dipping is in all cases very thin, the amount of gold precipitated corresponding with the quantity of the metal forming the base which has been dissolved.

Cold Gilding, or Gilding by the Rag.—This mode of gilding is chiefly employed upon silver, though sometimes also upon brass and copper. The operation is as follows: Dissolve 1.12 or 1.69 drachms of chloride of gold in as little water as possible, to which has previously been added 0.56 drachm of saltpetre. Dip in this solution small linen rags and, after allowing them to dry off, dry them in a dark place. These rags saturated with gold solution are then charred to tinder at not too great a heat, whereby the chloride of gold is reduced, partially to protochloride and partially to finely divided metallic gold. This tinder is then rubbed in a porcelain mortar to a fine uniform powder.

To gild with this powder dip into it a charred cork moistened with vinegar or salt water and rub, with not too gentle a pressure, the surfaces of the article to be gilded, which must be previously cleaned from adhering grease. The thumb of the hand may be used in place of the cork; but in both cases care must be had not to moisten them too much, as otherwise the powder takes badly. After gilding the surface may be carefully polished with the steel.

For cold gilding a solution of chloride of gold in an excess of cyanide of potash may also be used, after thickening the solution to a paste by rubbing in whiting. After zincking the metals the paste is applied by means of a cork, a piece of leather or a brush. Martin and Peyraud, the originators of this method, describe the operation as follows: Articles of other metals than zinc are placed in a bath consisting of a concentrated solution of sal-ammoniac, in which has been placed a quantity of granulated zinc. The articles are allowed to boil a few minutes, whereby they acquire a coating of zinc. For the preparation of the gilding composition dissolve 11.28 drachms of chloride of gold in a like quantity of water and add a solution of 2.11 ozs. of cyanide of potash in as little water as possible (about 2.82 ozs.). Of this solution add so much to a mixture of 3.52 ozs. of fine whiting and 2.82 drachms of pulverized tartar that a paste is formed which can be readily ap-

plied with a brush to the article to be gilded. When the article is coated heat it to between 140° and 158° F. After removing the dry paste by washing the gilding appears and can be polished with the burnishing-stone.

To Gild by Adhesion.—This process is chiefly employed upon sword-blades, gun-barrels and similar objects which are to be provided with gilded decorations. For this purpose the finely-polished article is coated with an etching ground prepared by melting together equal parts of resin, wax and black pitch and adding to the melted mass 1¼ parts of asphalt and 1½ parts of mastic. The desired design is then scratched in the etching ground and, after roughening the portions thus exposed with nitric acid and rinsing in water, the etching ground is removed with oil of turpentine. The object is then heated until it acquires a blue color, and a double layer of gold-leaf is then laid on the roughened portions and pressed down with the burnisher. As many gold leaves as desired may in this manner be laid on, but every two leaves must be burnished. Instead of roughening the portions to be gilded by etching with acid, the design is frequently scratched in the object with a sharp tool and the gold made to adhere in the manner described above by pressing and burnishing. This method requires, however, more gold than the first.

To Gild Steel.—Steel is best gilded as follows: Dissolve chloride of gold free from acid, in water, add three times the volume of the solution, of ether, and after 24 hours lift off the ethereal gold solution. Polished steel dipped in this solution is immediately beautifully gilded. By coating portions of the steel with lacquer or varnish beautiful designs can be produced. For other metals than steel, gilding by the galvanic process is to be preferred.

To Fire-gild Silver Objects.—Wrap several pieces of leaf-gold around a round cylindrical rod of silver, wrap the whole in paper, and, after securing it with thread or twine, heat it in a coal fire. The twine and paper, of course, char, but the gold at the same time unites firmly with the silver. The union of the metals may be still further increased by polishing with the burnisher or a burnishing-

stone of blood-stone. The rod of silver thus gilded can be drawn out to the finest wire.

To Fire-gild and Fire-silver Metals which Cannot be Amalgamated; for Instance, Iron and Steel.—First copper the objects, and then gild or silver in the usual manner with gold or silver amalgam. If damaskeening in gold or silver upon an iron or steel ground or *vice versa* is to be produced, the entire surface is first coppered. The places which are to be silvered or gilded are then coated with asphalt lacquer, and the article is dipped in solution of chromic acid, which dissolves the copper unprotected by the varnish, and leaves the iron or steel, which is not attacked by it, exposed. The varnish is then removed with oil of turpentine, and the gilding or silvering executed in the usual manner upon the coppered portion. For platinum the process is the same, but nitric acid is used instead of chromic acid.

To Give Gilt Articles a Beautiful Rich Appearance.—Pulverize and mix alum, 3 parts by weight; nitrate of potash, 6; sulphate of zinc, 3; and common salt, 3, with sufficient water to form a thinly fluid paste. Apply this paste as uniformly as possible to the objects by means of a brush, and when dry heat them upon a hot iron plate until the coating becomes black. Then wash in water, scratch-brush with wine-vinegar, dry, and polish.

According to a French direction, the same result is attained by pulverizing and mixing sulphate of copper (blue vitriol), 3 parts by weight; verdigris, 7; sal-ammoniac, 6; nitrate of potash, 6, with acetic acid, 31; dipping the gilt articles into the mixture, heating upon an iron plate until black, and, when cold, pickling with concentrated sulphuric acid.

Some practitioners *improve bad tints of gilding* by dipping the objects into a dilute solution of nitrate of mercury until the gilding shows a white amalgam; the mercury is then volatilized over a flame, and the object scratch-brushed. Others apply a paste of pulverized borax and water, heat until the borax melts, and then dip quickly in dilute sulphuric acid.

To Gild Articles of Metal.—The following process has been patented in Germany: A solution of aluminium nitrate and cobalt-

ous nitrate is evaporated and glowed. Of the residue 21.16 ozs. are melted together with 122.96 ozs. of red-lead, 28.21 ozs. of boric acid, and 7.05 ozs. of glass powder, pulverized finely and rubbed up with oil of turpentine. An acid solution of 3.52 ozs. of gold is mixed with 30.86 grains of tin and a like quantity of arsenious acid, and any acid present neutralized with ammonia. The objects to be gilded are first coated with the above-mentioned enamel and burnt, and then brushed with the gilding fluid and again burnt.

Imitation Gilding.—A very beautiful coating upon copper is obtained by boiling the objects, previously pickled very bright, in very dilute hydrochloric acid, to which have been added tartar and an amalgam of 1 part zinc and 12 parts of mercury. The articles, after being washed and dried, are heated to volatilize the mercury, and a gold-colored precipitate capable of taking a high polish will appear.

Gilding Powder for Copper, Silver, Brass, etc.—Mix protochloride of gold, 20 parts; cyanide of potash, 60; distilled water, 100; tartar, 5; and finely elutriated chalk, 100. By means of a clean woollen rag apply this mixture to the article to be gilded, which should previously be cleaned and drawn through a pickle of a mineral acid.

Gilder's Wax for Fire-gilding.—The wax used in fire-gilding serves for coloring the gold, and consists of an intimate mixture of yellow wax with finely pulverized verdigris, to which, as a rule, some bole, burnt alum or burnt borax is added. The theory of the use of gilder's wax is as follows: By the verdigris (cupric acetate) an actual red alloy is produced upon the surface of the article to be gilded. This is effected, 1, by the precipitation of copper from the melting mixture upon the zinc of the bronze; 2, by the co-operation of the products of the dry distillation of the wax and the acetic acid, the heated cupric oxide of the verdigris is reduced to copper which, as well as the copper precipitated upon the zinc, combines with the gold to a reddish gold alloy. The remaining ingredients serve only for the dilution of the active copper combinations, though some gilders claim to have observed that gilder's wax containing alum gives a lighter color than that

prepared with borax. Hence it is possible that in using gilder's wax containing alum an alloy of gold and aluminium is produced. For preparing gilder's wax there are a number of directions, of which those which have stood the test are here given. For all kinds of gilder's wax the separate constituents are pulverized and passed through a fine hair-sieve; the particles remaining in the sieve being further pulverized until all has passed through. The pulverized ingredients are then mixed, care being had to inhale as little as possible since verdigris is poisonous. Melt the wax in a clean pot, without, however, allowing it to become too hot, and gradually add the ingredients with constant stirring to prevent the heavier metallic particles from settling on the bottom. Then pour the mass, with constant stirring, into a suitable vessel, previously cooled and moistened with water, and after cooling cut it up into pieces.

I. White wax, 8 parts; verdigris, 2; cupric sulphate (blue vitriol), 2; borax, ¼.

II. White wax, 12 parts; Armenian bole, 3; verdigris, 1½; ferric sulphate, 2; burnt ochre, ½; and borax, ¼.

III. White wax, 12 parts; verdigris, 1½; copper-scales, 3; and borax, ¼.

IV. Yellow wax, 18 parts; red chalk, 8; cupreous water, 3; verdigris, 2½; borax, 1½; and burnt copper, 3.

V. Yellow wax, 18 parts; verdigris, 6; sulphate of zinc, 6; red chalk, 8½; copper scales, 4; ferrous sulphate (copperas), 3; colcothar, ½; and borax, ¾.

Quicksilver Water is a solution of mercurous nitrate, and is prepared by dissolving 10 parts of metallic mercury in 11 of cold nitric acid of 36° B., and diluting the solution with 275 parts of rain or distilled water. It serves for moistening bronze as well as copper, brass and German silver, and even silver of less fineness than $\frac{750}{1000}$, which do not take the gold amalgam well before gilding.

Iron-baths.—Depositions of iron serve chiefly for coating, or so-called steeling, of copper-plates, clichés, etc., to make them more capable of resisting mechanical wear. Galvanically precipitated

iron is extraordinarily hard, but also very brittle, and hence thick depositions are difficult to obtain. Moreover, in modern times nickelling the plates has been successfully substituted for steeling.

According to Varrentrap the following bath serves for steeling: Pure green vitriol, 4.75 ozs.; sal-ammoniac, 3.5 ozs.; water, 1 quart. Boil the water for ½ hour to remove all air, and after cooling add the green vitriol and sal-ammoniac. By the action of the air this bath separates ferric hydrate in flakes, and it must, therefore, be frequently filtered. It requires a current of 1 to 1.25 volts. To decrease the tendency of the bath to decompose, ammonio-ferrous sulphate may be used.

A simple solution of sal-ammoniac (3.50 ozs. of sal-ammoniac to 1 quart of water) may also be made into an iron-bath by hanging in iron sheets as anodes, suspending a copper-plate to the negative pole and allowing the current to circulate until a regular separation of iron is attained, which is generally the case in 5 to 6 hours.

For decorative purposes a deep-black deposition of iron may be produced as follows: Dissolve as large a quantity of steel-filings as possible in 50 quarts of commercial hydrochloric acid. The saturation of the solution is recognized by a sediment, which no longer dissolves, being formed on the bottom of the vessel. Then add 2 lbs. of white arsenic and vigorously stir the mixture. The arsenic dissolves very slowly; but the bath cannot be considered finished until all of it is dissolved, and the color obtained by means of the bath is the deeper the more complete the solution of the arsenic. The articles to be treated are connected to the negative pole of the battery, iron and carbon-plates serving as anodes. For a bath of 50 quarts two Bunsen elements about 7¾ inches high are required, and the bath being very acid the articles must be connected with the battery previous to immersion. Upon copper and brass the deposit is directly produced, but iron articles being attacked by the bath are first provided with a coat of nickel. The deposit of iron upon this nickel coating is very beautiful, and has been designated by the name of "black nickelling."

A steel bath recommended by Klein as doing good service con-

sists of a solution of equal parts of green vitriol and of sulphate of magnesia. The solution is kept neutral by suspending in it bags filled with carbonate of magnesia. The most suitable concentration of the solution corresponds to a specific gravity of 1.55, and, according to recent experiments, the density of current should at the utmost amount to 0.02 ampère per 61 cubic inches.

Lead-baths.—Dissolve by continued boiling, caustic potash, 1.75 ozs. and finely pulverized litharge, 0.17 ozs. in 1 quart of water. According to Watt the following solution is used: Acetate of lead, 0.17 oz.; acetic acid, 0.17 oz.; water, 1 quart. The bath prepared according to the first formula deserves the preference.

Lead baths require anodes of sheet-lead or cast-lead plates, a weak current, and frequent scratch-brushing of the articles in order to make the deposition more dense and to attain greater thickness. Iron is best first coppered. Superoxide of lead being separated upon the anodes, the latter must be frequently cleansed with the scratch-brush.

To Coat Metals with Lead.—A coat of lead protects metals from the effects of mineral acids and other chemical products, and, hence, vessels of lead or of leaded metal are much used in the chemical industries. Lead possesses, however, but little solidity and power of resistance, and apparatus, which has to resist a certain pressure, such as evaporating pans, crystallizing vessels, acid reservoirs, monte-jus, and, in general, apparatus for acid fluids and gases, is seldom made of it, that manufactured from leaded sheet-iron or sheet-copper being more durable. In a galvanic manner lead coatings can only be produced by means of a bath, which consists of a solution of oxide of lead in caustic potash or caustic soda. The fluid is prepared as follows: Dissolve 1 part of purified potash in 10 to 12 parts of water, and gradually add 1 part of burnt lime in the form of powder. To test whether the potash has been completely converted into caustic potash, mix a small sample of the fluid with dilute sulphuric acid. If no effervescence takes place the conversion is complete. Now separate the precipitate, which consists of carbonate of lime, from the caustic potash lye by filtering through strong linen. Then boil the lye in an iron kettle until it

shows a specific gravity of 1.33. When this is the case allow the lye to cool off, and then preserve it for future use in well-corked bottles. For use boil litharge in the lye until nothing more dissolves, and into this fluid, which represents the lead bath, place the object to be leaded. The object is connected to the cathode of the battery, a sheet of lead serving as the anode. In this manner all metals can be provided with a lead coating. It is best to previously copper iron in the galvanic manner. The same fluid can be used for leading brass and copper by contact. The thoroughly cleansed articles are suspended in the solution heated to the boiling point, and touched with a piece of tin. The articles immediately become coated with a coherent layer of lead, while the tin goes into solution. Coatings of lead are, however, more frequently produced in a dry way than by leading in the galvanic manner or by contact. The pickled sheets are dipped in a solution of sal-ammoniac, immediately dried, and then immersed in the lead bath. Lead not adhering well, especially to iron, this bath seldom consists of the pure metal, alloys of lead and tin, of tin, lead, and antimony, or of lead and zinc being generally used. According to a German patent, the metals to be leaded are pickled in an acid—for iron it is best to use dilute hydrochloric acid containing some zinc in solution—and then tinned upon one side. The thoroughly tinned, cleansed, and completely dry sheets are fixed horizontally with a narrow rim or border of sand or metal around them, and heated until the thin layer of tin upon the metal melts. Melted lead freed as much as possible from oxide is then poured over the surface of the sheets. The lead flows over the metal, and forming a lead-tin alloy with the layer of tin, coats the sheet with a layer of uniform thickness. A principal requisite is to heat the sheets to between 428° and 447° F., the temperature at which the layer of lead commences to melt. Small irregularities due to pouring the metal are removed by hammering or passing the leaded sheets through an ordinary plate-roll. Sheets of metal prepared in this manner can be bent, rivetted, and hammered without causing a separation of the lead from the other metal.

Improved Method of Covering Articles of Iron with Lead.—The

article of iron or steel is first cleaned (preferably by steel brushes), then roughened by a sand-jet blower, washed over with a soldering liquid, and plunged into a bath of molten lead. While in the bath the article is brushed with steel brushes to insure intimate contact between the lead and iron. The layer of lead thus obtained is too thin to protect the iron from the action of acids, and the article is subjected to a second operation. If it be a plate of iron or steel it is fixed horizontally, with a narrow rim or border placed round it, and it is then washed over with a soldering liquid, heated to about 750° F., and molten lead is poured over its surface and uniformly distributed. The height of the rim determines the thickness of the layer of lead. The whole is then again heated to a temperature above the melting-point of lead, and the surface again brushed with steel brushes. The plate is then allowed to cool, care being taken during the cooling of the sheet-iron or plate to keep the layer of lead as long as possible above the melting-point of lead by fresh additions of small quantities of molten lead. In the case of pipes, boilers, or similar vessels, a suitable "core" or casing is provided, and after treating the surface with soldering liquid and heating to 752° F., the space between the article and the "core" is filled with molten lead. The whole is then again heated above the melting-point of lead, and finally allowed to cool slowly, the lead again being kept as long as possible in a molten state.

Leyson's Process of Leading.—The iron, sheet or wire, is first pickled bright with acid, then brought into a solution of sal-ammoniac, and dried. The melted lead is in an iron kettle or box, whose upper cross-section is separated by a bridge-like partition, so that it dips only very slightly into the melted lead. The lead on one side of this partition is covered with sand, while on the other side a few pieces of sal-ammoniac are thrown upon the surface to prevent the formation of oxide. It is necessary to compound the lead with some zinc, which is effected by stirring about every half hour with a zinc rod dipped in a solution of sal-ammoniac, whereby for every 330 lbs. of lead about 8.46 drachms of zinc alloy are added. The iron sheets, previously pickled, washed in solution of

sal-ammoniac, and quickly dried with the assistance of heat, are then immersed in the lead bath prepared in the manner above described. The sheets are introduced from the sal-ammoniac side, carried through under the partition by means of tongs, and drawn out through the layer of sand.

Alloys for Hot Leading.—I. Lead, 9 parts; tin, 1; antimony, 1. Melt under a cover of common salt, to which some chloride of barium may be added. The pickled sheets of iron are immersed in the melted mixture.

II. Lead, 7 to 8 parts; tin, 1 part; this alloy may be improved and made more durable by the addition of some zinc and antimony.

III. An alloy with 1 to 2 per cent. of tin and 6 per cent. of arsenic is claimed to adhere well to iron, but on account of its great content of arsenic it could only be used in very few cases.

IV. Tin, 3 parts; lead, 16; copper, 1; and antimony, 1; *or*, tin, 3 parts; and lead, 17.

Nickel Baths.—The extensive application of nickel-plating is due to the elegant appearance of the plated ware, the constancy of nickel when exposed to atmospheric influences, its hardness, and the ease with which the operation is executed.

Preparation of the Metals to be Nickelled.—Iron and steel are immersed for some time in boiling hot solution of caustic soda or potash, then thoroughly brushed, rinsed in cold water and finally dipped in an acid pickle of 1 part of sulphuric acid, 2 of hydrocholoric acid and 10 of water, after which they are again rinsed, thoroughly rubbed with fine, washed pumice-stone or Vienna lime, rinsed off and at once brought into the bath. Fine polished instruments of iron and steel for surgical, dental and other purposes, scissors, knives and telegraph instruments are treated in the same manner, but in place of the washed pumice-stone they should be brushed with whiting or tripoli, or, what is still better, with infusorial earth. Brass, bronze, Britannia metal, etc., are also treated with a hot solution of caustic soda or potash, then rubbed and brushed, rinsed in water and at once placed in a solution of potassium cyanide in water (8½ ozs. of potassium cyanide to 4 quarts

of water). They are then cleansed with a bristle brush kept for that purpose, carefully rinsed in water and at once brought into the bath. The variegated colors produced upon brass by the action of the solution of caustic soda disappear almost instantaneously in the solution of cyanide, and a bright surface of the metal is sure to be obtained. Special attention must be paid to the careful rinsing of the articles, especially if they have hollow places and depressions, after they have been treated in the solution of cyanide of potassium, to prevent the nickel bath from being spoiled by the cyanide. For many articles of brass having more or less dull and finely polished places it is sufficient to dip them, after having been freed from all fatty substances by boiling caustic soda lye and subsequent rinsing in water, into the mixture of acids, then to rinse them again and bring them at once into the bath. For iron castings or filed articles the use of finely-sifted pumice or chalk is absolutely necessary. Copper wire should be tightly wound around all metallic articles and two or more wires around large articles. With articles consisting of two metals, for instance iron with steel, or with brass, the wire must be wound around both metals. Smaller articles are suspended from copper hooks. The articles should not be immersed in the nickelling bath until the battery or dynamo is in action. The objects remain in the bath until they have acquired a white color, which will require from 5 to 30 minutes, according to the strength of the current and the number and size of the articles suspended. Large objects of steel or iron require longer than brass, copper, etc., and, if they fill the bath entirely, must remain in it, according to circumstances, for several hours or an entire night. In case the article to be nickelled assumes a gray or black color, or feels gritty or rough, the current is too strong. The appearance of a yellowish white coloration is due to too weak a current. The article after its removal from the bath should immediately be dipped for a few seconds in boiling water, then allowed to drain off, dried in warm saw-dust free from rosin and, if necessary, polished. Fine articles are rubbed with a polishing brush or with soft leather and whiting. Burnishing the nickelled articles with the steel is not admissible, as the coating is too hard

and too brittle for such usage. The better the articles have been polished *before* plating the more beautiful the nickelling will be.

The composition of the baths depends partially on the nature of the metals to be nickelled. While one and the same bath may be used for nickelling all kinds of metal, some compositions offer greater advantages for nickelling certain metals, on account of the greater whiteness of the deposit obtained and the weaker current required, etc. It is always best to use several baths and not to nickel all kinds of metals in one and the same bath. It is, for instance, entirely wrong to nickel zinc articles, even when previously coppered in a bath in which iron and brass are treated.

A further requirement in nickelling is the use of pure nickel salts free from other metals; the anodes must also be made of pure nickel.

Boric acid, recommended by Weston as an addition to nickel baths, as well as to other galvanic baths, has a favorable effect upon the pure, white separation of nickel, especially in nickelling unground surfaces.

The most Simple Nickel Bath consists of a solution of 8 to 10 parts by weight of pure double sulphate of nickel and ammonium in 100 parts by weight of distilled water; the solution if too acid is neutralized to a slightly acid reaction with spirits of sal-ammoniac. The solution is prepared by boiling the salt with the corresponding quantity of water, using in summer 10 parts of nickel salt to 100 of water, but in winter only 8 parts, to prevent the nickel salt from crystallizing out. This bath requires a strong current and cast nickel anodes.

Weston's Solution.—Double sulphate of nickel and ammonium, 10 parts; refined boric acid, 2½ to 5; water, 150 to 200. The nickel salt and boric acid may be dissolved separately in boiling water, the solutions mixed and the volume brought up to that of the formula, or the two components may be dissolved together.

Pott's Solution.—Acetate of nickel, 2¾ parts; acetate of calcium, 2½; water, 100. To each gallon of this solution add 1 oz. acetic acid 1.047 specific gravity.

To prepare this bath dissolve about the same quantity of the dry carbonate of nickel as that called for in the formula (or three-quarters of that quantity of the hydrated oxide) in acetic acid, adding the acid cautiously and heating until effervescence has ceased, and solution is complete. The acetate of calcium may be made by dissolving the same weight of carbonate of calcium (marble dust) as that called for in the formula (or one-half that quantity of caustic lime) and treating it in the same manner. Add the two solutions together, dilute the volume to the required amount by the addition of water, and then to each gallon of the solution add 1 oz. of free acetic acid.

Powell's Solutions.—I. Sulphate of nickel, 6 parts; citrate of nickel, 3; phosphate of nickel, 3; benzoic acid, 1½; water, 200.

II. Phosphate of nickel, 10 parts; citrate of nickel, 6; pyrophosphate of sodium, 10; bisulphide of sodium, 1½; citric acid, 3; aqua ammonia, 15; water, 400. These solutions yield good results, but their complex composition must debar them from general use.

The following bath is much used in this country, and is especially suitable for nickelling ground surgical instruments, as well as all ground iron articles which are to be thickly and solidly nickelled. It is also excellent for solid nickelling of copper, brass and bronze. The deposit of nickel is white, dense and hard, and hence takes a high polish without danger of the nickel grinding off. The bath is prepared by dissolving the salts in boiling water, and when cool adding small fragments of ammonium carbonate until the bath is neutral to test-paper. It is composed of sulphate of nickel and ammonium, 25½ ozs.; ammonium sulphate, 7.9 ozs.; crystallized citric acid, 1¾ oz.; water, 10 to 12 quarts. It requires a current of 2 to 2.2 volts.

Baths for Rapidly Nickelling Cheap Articles.—I. Chloride of nickel and sal-ammoniac each, 1.75 ozs.; water, 1 quart; or, II. Sulphate of nickel and ammonium, 2 ozs.; sal-ammoniac, 1 oz.; and water, 1 quart. If too acid, neutralize both solutions with

spirits of sal-ammoniac. The bath prepared with chloride of nickel is preferably used for nickelling zinc lamps.

Nickel Baths for Special Purposes.—I. Sulphate of nickel and ammonium, 10½ ozs.; potassium citrate, 7 ozs.; ammonium chloride, 10½ ozs.; water, 10 to 12 quarts. To prepare the bath dissolve 10½ ozs. of nickel sulphate and 3½ ozs. of pure crystallized citric acid in water, neutralize accurately with caustic potash and then add the ammonium chloride. This bath is especially adapted for quick nickelling of polished *zinc wares* previously slightly *coppered*. The deposition is effected with a very feeble current without the formation of black streaks such as otherwise are apt to appear in nickelling with a feeble current. The deposit itself is dull and somewhat gray, but acquires a very fine polish and pure white color by slight treatment upon the polishing disks. With a stronger current the bath is also suitable for the direct nickelling of zinc articles; it must, however, be kept strictly neutral. The bath works with rolled anodes, and requires but seldom a correction of the reaction.

II. Phosphate of nickel, 8½ ozs.; sodium pyrophosphate, 26¼ ozs.; water, 10 to 15 quarts. Dissolve the sodium pyrophosphate in water, heat the solution to about 167° F. and add the phosphate of nickel with constant stirring. The phosphate of nickel is obtained as a pale green powder by precipitating solution of nickel sulphate with sodium phosphate. This bath yields a very fine dark nickelling upon *iron*, *brass*, *copper*, *etc.*, as well as *directly* without previous coppering upon *sheet zinc* and *zinc castings*, and may be advantageously used for decorative purposes where darker tones of nickel are demanded.

III. A fairly good nickel bath for electro-platers, having but a feeble current at their disposal, is obtained from a solution of sulphate of nickel and ammonium, 22¾ ozs.; sulphate of magnesia, 11¼ ozs.; water, 10 to 12 quarts. This bath precipitates readily and strongly, and a thick coating can be deposited upon *iron* without fear of peeling off; even *zinc* may be directly nickelled with a comparatively feeble current. The deposit is, however, rather

soft, with a yellowish tinge, and the bath does not remain constant as the anodes are but slightly attacked.

New Nickel Baths.—I. The following formulæ have been recently recommended, but do not offer any advantages over those previously given.

I. Dissolve 25½ ozs. of neutral ammonium tartrate, 35¼ ozs. of sulphate of nickel, and 77 grains of tannin in 20 quarts of water.

II. Dissolve 17½ ozs. of sulphate of nickel, 9¼ ozs. of tartaric acid and 2¼ ozs. of caustic potash in 10 quarts of water.

In nickelling, either cast or rolled plates of nickel are used as anodes, some baths requiring cast anodes besides rolled anodes in various proportions; it can here only be indicated that the correct proportion is that by which the original acidity of the bath is maintained during the operation.

As regards the surface of the anodes to be suspended in the bath, it may be laid down as a rule that it should be at least equal in size to the surface of the articles to be nickelled; in most cases it is, however, best that it should be larger. For suspending the anodes it is best to use strong hooks of pure nickel wire; with flat articles the distance of the anodes from them should be from 3¾ to 4¾ inches, and correspondingly more with objects in high relief.

Careful regulation of the current is required for the production of thick deposits. The following may be laid down as a rule: In 2 or 3 minutes the articles should show themselves plainly and everywhere coated with nickel, and no violent development of gas bubbles should be seen. If a deposit of nickel is not observed after 2 or 3 minutes the current is too feeble, and if, on the other hand, a strong development of gas takes place, the current is too strong; in the first case the current must be strengthened and, in the latter, decreased; as otherwise the articles are apt to "burn," that is, the metal will be precipitated as a dark-gray or black deposit which discolors and renders it useless.

With a correctly regulated current it must be possible to allow the articles to remain in the bath, without burning, for ½ to 2 hours,

according to the composition of the bath. The sufficient thickness of the deposit is recognized by the dead-bluish tinge the articles assume; when in this state they take up but little more nickel and, if they are to have a thicker deposit, must be scratch-brushed and then quickly returned to the bath. Articles to be coated with a thick deposit must be turned in the bath, that is, they must after some time be so suspended that the portions which first were down come up. Copper, brass, bronze, German silver, iron and steel are generally nickelled directly; but zinc, tin, lead and Britannia ware are coppered or brassed before nickelling. Small articles which cannot be suspended are nickelled in a sieve, it being best to heat the bath for this purpose. The nickelled articles are thoroughly rinsed in water, then immersed in hot water until they have acquired the temperature of the water, dried in saw-dust and finally polished.

Nickelling of Knife-blades, Sharp Surgical Instruments, etc.— Most electro-platers experience considerable trouble in nickelling sharp-edged instruments, the edges and points being invariably spoiled either by the deposit of nickel or in polishing. The following directions are given for the convenient nickelling of such instruments without any damage being done to the edges.

New articles, which have not been used, require no special preparation. they being at once freed from grease and brought into the bath. But instruments which have been used and are partly or entirely coated with rust must first be ground after the removal of the rust by chemical or mechanical means. The marks left by the stone or emery-wheel are effaced by means of the circular brush. But in brushing the edges become again dull if special precautionary measures are not used. For instance, the edge of a knife-blade must never come in contact with the brush. This is prevented by firmly pressing the blade flat upon a soft support of felt or cloth, so that the edge sinks somewhat into the support without, however, cutting into it. The edge is then held downward and thus together with the support brought against the revolving brush. In this manner the blades can be vigorously brushed without fear, of spoiling the edges.

The treatment in giving them a high polish after nickelling is the same. Freeing from grease may be done in the usual manner with lime-paste, but must also be effected upon a soft support, the same as in polishing. After thorough rinsing in clean water the separate pieces, *without* being previously coppered, are brought directly into the nickel bath, the composition of which must, of course, be suitable for nickelling steel articles. The instruments are first coated with the use of a strong current, the operation being then continued with a weak current, so that the deposition takes place slowly and with great uniformity.

In suspending the articles in the bath care should be had that neither a point nor an edge is turned towards the anodes. It is best to use a bath with anodes only on one side, or to interrupt the positive conduction on one side, and to suspend the blades with their backs towards the anodes. If, for any reason, the instruments are to be suspended between two rows of anodes, the edges should be uppermost as near as possible to the level of the bath; they should never hang deep or downwards.

Phenomena which may Occur in Nickelling, and the Means of Avoiding them.—1. The articles do not become coated with nickel but acquire discolored, generally darker, tones. *Reasons:* The current is either too feeble to effect a separation of nickel, and the discoloration is due to the chemical action of the nickel solution upon the constituent metals of the articles. *Remedy:* Increase the current or diminish the surface of suspended articles; also examine whether the current actually passes into the bath, otherwise clean the contacts.

2. A deposition of nickel takes place, but it is dark or spotted or marbled, even with a sufficiently strong current. *Reasons:* The bath is either alkaline, which has to be ascertained by litmus paper and, if so, the slightly acid reaction of the bath must be restored by the addition of a suitable acid; *or*, the bath is too concentrated, in which case a separation of crystals will be observed; this is remedied by diluting with water; *or*, the nickel solution is very poor in metal, which can be remedied by the addition of nickel salt; it should also be tested as to the admixture of copper,

since the production of dark tones is frequently due to this; in this case the bath is allowed to work for some time, and if the content of copper is inconsiderable a white deposit will soon be obtained; *or*, the cleaning and dipping of the articles has been incomplete, which is remedied by again thoroughly cleaning them; *or*, the conducting power of the bath is insufficient, which is remedied by the addition of a suitable conducting salt.

When freshly prepared baths yield dark nickelling it can generally be remedied by working the bath 2 or 3 hours.

3. A yellowish tinge of the nickelling. *Reasons:* Alkalinity of the bath. *Remedy:* See under 2; or, with cast-iron, an insufficient metallic surface, which is remedied by repeating the scratch-brushing; *or*, unsuitable composition of the bath.

4. The articles rapidly acquire a white deposit of nickel, but the color soon changes to dull gray-black, especially on the deepest corners and edges. *Reason:* Too strong a current. *Remedies:* Regulating the current, or hanging in more articles, or taking out elements. Frequent turning of the articles.

5. The nickelling is white, but readily peels off by scratching with the finger-nail, or by the action of the polishing-disk. *Reasons:* The current is either too strong, which is remedied as under 4; *or*, the bath is too acid. This is remedied by the addition of spirit of sal-ammoniac, potassium carbonate or carbonate of nickel, according to the composition of the bath; *or*, insufficient cleaning and dipping, which is remedied by thorough cleaning after removing the unsuccessful deposit and, if it cannot be entirely removed, coppering.

6. Though nickelling may proceed in a regular manner some places remain free from deposit. *Reasons:* Either some of the surfaces of the articles touch each other, or air-bubbles are inclosed in cavities; *or*, faulty arrangement of the anodes. *Remedy:* Removal of the causes.

7. The deposit appears with small holes. *Reasons:* A deposit of particles of dust upon the articles. *Remedy:* Remove the dust from the surface. When there is a general turbidity of the bath in consequence of alkalinity, add the most suitable acid and boil and

filter the bath; *or*, insufficient removal of gas-bubbles from the articles. *Remedy:* Shake the negative poles by blows with the finger.

8. Deposition takes place promptly upon the portions of the articles next to the anodes, while deeper portions remain free from nickel or become black; or the portions covered by the suspending wire show dark lines. *Reason:* Insufficient conducting power of the bath. With large depressions this is not remedied by the addition of a suitable conducting salt, but requires treatment with the hand anode.

To Improve Defective Nickelling.—With the brass parts thoroughly cleansed defective places should not occur, but when they happen by accident or negligence recourse is had to the so-called "doctor." This consists of a piece of nickel anode connected to the positive pole by a thin copper wire. Around this piece of nickel, which is about the size of a finger, a piece of ordinary muslin is wrapped several times. The defective article is then held on top of the positive pole, and, after dipping the piece of nickel in the nickel solution until the muslin is thoroughly soaked, it is moved to and fro over the defective place, a nickel coating being thus formed. Defects in gilding or silvering may be remedied in the same manner, a piece of gold or silver and the corresponding solution being of course used.

To Nickel Polished Objects of Iron or Steel Without the use of a Battery.—The method of coating metallic objects with a thin layer of nickel without the use of a galvanic battery consists in placing the article to be nickelled in a solution of chloride of zinc and a nickel salt. Since, however, by this method of nickelling, stains may readily occur where the metal comes in contact with the zinc, which afterwards would have to be removed by polishing, a special process is employed. To a dilute 5 to 10 per cent. solution of chloride of zinc add enough nickel sulphate to give the solution a deep green-color, and then heat, best in a porcelain vessel, to the boiling point. Then, without troubling about the turbidity of the bath caused by the separation of a basic nickel salt, immerse the articles, previously cleansed and freed from grease, in it in such a

manner that they do not touch each other, or at least only in a few places, and keep the whole boiling for 30 to 60 minutes, from time to time replacing the water lost by evaporation. During the boiling a bright layer of nickel is precipitated upon all portions of the objects free from grease or oxide. The boiling may without injury be continued for hours, though the thickness of the layer of nickel will not be essentially increased thereby. The articles being uniformly nickelled are taken from the bath, rinsed off in water, holding some chalk in suspension, and then carefully dried. The layer of nickel thus produced will bear polishing with chalk, and the process may be recommended for articles requiring a thin but firmly adhering coating. The chloride of zinc used must not contain any metal precipitable by iron. Where commercial chloride of zinc of a sufficiently good quality cannot be had, it is best prepared by dissolving zinc waste in pure hydrochloric acid and allowing the solution to stand with an excess of zinc for the precipitation of metals precipitable by zinc. After 24 hours the solution is filtered off and is ready for use, whereby it has to be taken into consideration that it contains for every part of dissolved metallic zinc nearly 2.1 parts of chloride of zinc. The nickel sulphate used should also be as pure as possible, and the cold solution, when brought in contact with bright iron, must especially not deposit any metal, for instance, copper, precipitable by iron. During the operation, when in consequence of the formation of a layer of nickel, the bath shows a pale green color, fresh nickel salt must be added until the intense green color reappears. The fluid used for nickelling separates, on standing in the air, ferric hydrate, from which it is freed by filtering, and it can then be repeatedly re-used for nickelling after adding some solution of chloride of zinc and nickel sulphate. With the use of cobalt sulphate a lustrous layer of metallic cobalt can in the same manner be precipitated upon polished objects of iron and steel.

To Imitate Nickel-plating.—A sort of light nickel-plating is obtained by heating a bath of pure granulated tin, crude tartar and water to the boiling point and adding some nickel oxide heated to a red-heat. A brass or copper object immersed in the solution

becomes immediately coated with nearly pure nickel. By adding some carbonate or tartrate of cobalt the fluid acquires a bluish coloration, the intensity of which depends on the quantity of cobalt used. While this method cannot be advantageously used for plating on a large scale it is serviceable for small work.

Platinum Baths.—The platinum baths formerly proposed did not yield quite satisfactory results, the content of platinum being too small in some of them, and with others dense deposits could not be obtained. A new formula by Böttger gives, however, quite a good bath. A moderately dilute boiling solution of sodium citrate is added to platoso-ammonium chloride until an excess of the latter does no longer dissolve even after continued boiling. The following proportions have been found very suitable: Dissolve 17½ ozs. of citric acid in 2 quarts of water, and neutralize with caustic soda. To the boiling solution add, with constant stirring, the platoso-ammonium chloride freshly precipitated from 2.64 ozs. of platinum chloride, heat until solution is complete, allow to cool and dilute with water to 5 quarts. To decrease the resistance of the bath to conductivity 0.7 or 0.8 oz. of sal-ammoniac may be added; a larger addition, however, causes the separation of dark-colored platinum.

The platoso-ammonium chloride is prepared by adding to a concentrated solution of platinum chloride concentrated solution of sal-ammoniac until a yellow precipitate is no longer formed on adding a further drop of sal-ammoniac solution to a filtered sample of the fluid. The precipitate is filtered off and brought into the boiling solution of sodium citrate. This bath works very uniformly if the content of platinum is from time to time replenished.

"The Bright Platinum Plating Company," of London, has recently patented the following composition of a platinum bath: Chloride of platinum, 0.98 oz.; sodium phosphate, 19¾ ozs.; ammonium phosphate, 3.95 ozs.; sodium chloride, 0.98 oz.; and borax, 0.35 oz., are dissolved with the aid of heat in 6 to 8 quarts of water, and the solution is boiled for 10 hours, the water lost by evaporation being constantly replaced. The results obtained with this bath are not much better than those with Böttger's bath.

The following bath has been recommended by Prof. Silvanus P. Thompson: Chloride of platinum, 2 parts; sodium borate, 16; sodium carbonate, 16; sal-ammoniac, 2; water, 150.

Platinum baths must be used hot, and even then require a current of 5 to 6 volts tension. An abundant development of gas must appear on the articles and the anodes; the surface of the anodes (platinum anodes) must not be too small, and must be only a few centimetres distance from the articles. Since the platinum anodes do not dissolve, the content of platinum in the bath becomes constantly smaller, and the bath must from time to time be strengthened. It is then heated in a porcelain dish or enamelled iron vessel to the boiling-point, some fresh solution of sodium citrate is added, and platoso-ammonium chloride introduced as long as it dissolves. A concentrated solution of platoso-ammonium chloride may be kept on hand, and a small quantity of it at intervals be added to the bath.

To Platinize Copper.—Dissolve platinum in aqua regia, and precipitate the solution with sal-ammoniac. Dilute this precipitate with much water, and expose it in a well-luted receiver to a moderately strong heat for half an hour until the receiver is glowing hot. By this process the precipitate is converted into a gray powder, which is nothing else but very finely divided platinum. A portion of this powder is rubbed with 5 parts of mercury in a thoroughly heated mortar. From the mass thus obtained a thick amalgam is formed, to which 2 parts more of mercury are added in order to make it more pliant. This platinum amalgam when applied to polished copper adheres very firmly. The operation succeeds still better by mixing some chalk with the amalgam. Copper coated in this manner with platinum acquires by polishing the lustre of silver.

To Platinize by the Wet Method.—The fluid required for coating metals by this method with a layer of platinum is prepared by dissolving 1 part of chloride of platinum and 1 part of pure honey in 8 parts of water, adding to the solution 6 parts of spirits of wine and 2 of ether, and filtering the mixture if necessary. After thoroughly cleansing and drying the articles, heat them over a flame,

but so that they do not touch it, not quite to a red heat, and then suddenly immerse them in the platinizing solution. Generally, immersing for one minute suffices, but if necessary repeat the operation, the articles, before heating, being again washed and dried. The solution of platinum may be weaker or stronger than that given above, and of course the appearance of the layer of platinum deposited upon the articles will be accordingly. It will be readily seen that this process is only suitable for small objects, the consumption of alcohol and ether making it rather expensive.

Metals can also be coated in the wet way with a layer of platinum by cleansing them thoroughly and then putting them in a solution of 1 part of platoso-ammonium chloride in 64 parts of water heated to 167° F. In the course of 1 to 5 minutes they are taken out, and the coating of platinum polished with whiting.

A moistened mixture of platoso-ammonium chloride and tartar may be used for platinizing in the cold way, while for platinizing by boiling a solution of chloride of platinum rendered slightly alkaline with carbonate of soda is used. The articles are immersed into the solution, previously heated to between 131° and 140° F., and when taken out rinsed in water, and rubbed with soft, dry leather. All the coatings obtained by the processes given above are very delicate, but they produce splendid effects upon ornaments and statues. It is recommended to protect them with a varnish of wax dissolved in oil of turpentine, or of paraffine dissolved in benzine.

To Coat Metals with Platinum in a Cheap Way.—Iron articles are first coated with a mixture of borate of lead, oxide of copper, and oil of turpentine, and then exposed to a temperature of between 482° and 626° F., whereby the coating fuses and spreads uniformly over the iron, penetrating its pores. If the articles are to have a smooth surface (enamel-like appearance) a second coating consisting of borate of lead, oxide of lead, and oil of lavender, is in the same manner applied to the first. Upon both coatings a thin, uniform layer of platinum can be readily deposited by the application by means of a brush (or for smaller objects by immersion) of a solution of dry platinic chloride in ether and volatile oils, and

evaporating the fluid at a temperature not exceeding 392° F.; very finely divided platinum is separated, which adheres firmly to the surface. If the articles have been provided only with the first-mentioned coating the precipitated platinum shows a dull color. Such treatment suffices for articles which are simply to be protected from wear and tear. For the attainment of decorative effects it is, however, recommended to provide the articles to be platinized with both the coatings mentioned above. The many uses to which this process can be put, as well as its cheapness and the great power of resistance of the coating, make it of special value for large industries.

Silver Baths.—These are solutions of silver salts in potassium cyanide, the content of silver varying from 0.35 to 0.88 oz. of fine silver per quart, according to the desired thickness of the deposit. For ordinary galvanic silvering 0.35 oz. of fine silver (= 0.56 oz. of nitrate of silver, or 0.47 oz. of chloride of silver) is dissolved in a solution of 0.7 oz. of 98 per cent. potassium cyanide in 1 quart of water.

For heavy silvering of knives, forks, etc., a stronger bath is used: 0.88 oz. of fine silver (= 1.17 oz. of chloride of silver, or 1.03 oz. of cyanide of silver) is dissolved in a solution of 1.75 oz. of 98 per cent. potassium cyanide in 1 quart of water.

No accurate statement can actually be made in regard to the content of potassium cyanide in the bath, as it depends on the strength of the current used. With a very weak current, and consequently slow precipitation, somewhat more potassium cyanide may be used than with a stronger current and more rapid precipitation. The appearance of the anodes, for which sheets of fine silver are used, moreover, indicates whether the bath contains too much or too little potassium cyanide. They should become gray during silvering, and gradually reassume their white color after the interruption of the current. If they remain white during silvering the bath contains too much potassium cyanide, and, if they turn black and retain this color after the interruption of the current, potassium cyanide is wanting. With a correct content of potassium cyanide a beautiful, fine-grained deposit is obtained, with a strength of

current of 0.15 to 0.25 ampères per 15½ square inches and 0.5 to 0.75 volt. The deposit of silver is always dull.

It is claimed that by the addition of some bisulphide of carbon, tar oil, etc., to the silver bath a lustrous instead of a dull coating is obtained. Some bisulphide of carbon is added to a small quantity of the silver bath, and after thorough shaking, some of this fluid which has absorbed small quantities of bisulphide of carbon is added to the silver bath.

It is advisable to frequently move the articles to be silvered in the bath, as otherwise streaks are apt to form; in large electro-plating establishments the articles are kept in constant motion by mechanical devices.

Before silvering the metals must first be prepared; if silver were directly precipitated upon copper, brass or German silver, the coating would not adhere, and to attain this the metals must first be amalgamated. This is done by dipping the articles, previously freed from grease, in a dilute solution of mercurous nitrate (30 to 150 grains per quart); they remain in the solution only long enough to become uniformly white. They are then rinsed in water, brushed off with a soft brush and immediately brought into the silver bath. Iron, steel, nickel, zinc, tin, lead and Britannia ware must first be coppered and then amalgamated before being brought into the silver bath.

The articles remain in the bath until they show a dead-white coating (10 to 15 minutes), when they are taken out, brushed with a not too fine brass scratch-brush to ascertain that the deposit adheres, freed from grease, amalgamated and again brought into the bath, where they remain until the required thickness of the deposit is obtained. Before taking the articles from the bath they are allowed to remain suspended for a few seconds, with the current shut off or reversed, which prevents the deposit from turning yellow.

If the articles are to retain the beautiful white crystalline mat with which they come from the bath, they must, without being touched with the fingers or striking against the sides of the vessel, be thoroughly rinsed in water, then dipped in clean hot water and

hung up free to dry. Immediately after drying they must be provided with a coating of colorless lacquer, as the silver quickly turns yellow, and besides is very sensitive.

Forks and spoons of German silver are frequently silvered so that the deposit is thicker on the places subject to the most wear. This is effected by laying the silvered articles between plates of gutta-percha of a corresponding shape, and held together by rubber bands. In these plates the places to be further silvered are cut out. By suspending the forks and spoons thus covered in the bath the unprotected places receive a further layer of silver, the outlines of which are later on smoothed down with the burnisher.

The silvered articles are finally scratch-brushed, they being frequently moistened during this operation with decoction of soap-root; they are then dried in clean, fine saw-dust, and finally receive a high lustre by polishing with the steel or blood-stone.

Silvering by Contact.—For silvering by contact with zinc the following bath may be used: 98 per cent. potassium cyanide, 8.11 to 8.81 ozs.; fine silver (in the form of chloride of silver or nitrate of silver), 3.52 ozs.; distilled water, 10 quarts. To prepare this bath dissolve 5.64 ozs. of chemically pure crystallized nitrate of silver in 5 quarts of distilled water, then dissolve the potassium cyanide in the remaining 5 quarts and mix both solutions. The articles to be silvered must be thoroughly cleansed by pickling and amalgamated by dipping into a solution of 0.35 oz. of nitrate of mercury in 1 quart of water, to which, gradually and with constant stirring, pure nitric acid is added until a clear fluid results. In this mercury solution the articles remain until they are uniformly covered with a white coating. They are then rinsed off in water and, in case the amalgamation shows a gray instead of a white tint, brushed. Before placing the articles in the bath they are wrapped round with bright zinc wire or are brought in contact with a bright strip of zinc while in the bath, care being had to frequently change the points of contact to prevent the formation of stains. By the contact of the metal to be silvered with the electro-positive zinc, a weak current is produced which effects the deposition of the silver; but this taking place very slowly, it is best to heat the silver

bath. At the same time silver is precipitated upon the zinc and hence the latter must be frequently freed from the precipitate and brightened by means of a file or emery-paper.

Silvering by Dipping.—For silvering by this process articles of copper, brass or any other alloy of copper, as well as coppered and brassed wares, the following solution is recommended: Crystallized nitrate of silver, 5.64 drachms; 98 per cent. potassium cyanide, 1.23 ozs.; water, 1 quart. To prepare the bath dissolve the silver salt in 1 pint of distilled water, then the potassium cyanide in the remaining pint of water and mix the two solutions. The bath is heated in a porcelain or enamelled iron vessel to between 176° and 194° F. and the thoroughly cleansed and pickled articles immersed in it until they are uniformly silvered; previous amalgamation is not necessary. The precipitate is lustrous if the articles are left but a short time in the bath, but becomes dull when they remain longer; in the first case the deposit of silver is a mere film and, while it is somewhat thicker in the latter, it can under no circumstances be called solid.

According to Dr. Ebermayer the composition of a silver bath for dipping is as follows: Dissolve 1.12 ozs. of nitrate of silver in water and precipitate the solution with caustic potash; then thoroughly wash the precipitated silver oxide and dissolve it in 1 quart of water, which contains 3.52 ozs. of potassium cyanide in solution, and finally dilute the whole with 1 quart more of water. For silvering the bath is heated to the boiling point, and the silver withdrawn may be replaced by the addition of moist silver oxide as long as complete dissolution takes place. When the silvering is no longer beautiful and of a pure white color the bath is useless and is then evaporated.

Blanching.—The process known under this name is used for coating with a thin film, or rather coloring, with silver small articles, such as hooks and eyes, pins, etc. It differs from the above-described dipping process, which effects the silvering in a few seconds, in that the articles require to be boiled for a longer time. The process is as follows: Prepare a paste from 14.11 drachms of nitrate of silver precipitated as chloride of silver, 44 ozs. of cream of tartar and a like quantity of common salt, by precipitating the

solution of the nitrate of silver with hydrochloric acid, washing the chloride of silver and mixing it with the above-mentioned quantities of cream of tartar, common salt and sufficient water to a paste, which is kept in dark glass to prevent the chloride of silver from being decomposed by the light. Small articles of copper or brass are first freed from fat and pickled. Then heat in an enamelled kettle 3 to 5 quarts of rain water to the boiling point, add 2 or 3 heaping tablespoonfuls of the above-mentioned paste and bring the metallic objects contained in a stone-ware sieve into the bath and stir them diligently with a rod of glass or wood. Before placing a fresh lot of articles in the bath the addition of silver paste must be renewed; if finally the bath acquires a greenish color, caused by the dissolved copper, it is no longer suitable for the purpose, and is then evaporated and added to the silver residues.

Cold Silvering.—In this process an argentiferous paste composed as given below is rubbed by means of the finger, a piece of soft leather or a rag upon the cleansed and pickled metallic surface (copper, brass or other alloys of copper) until it is entirely silvered. The paste may also be rubbed in a mortar with some water to a thinly fluid, uniform mass which is applied with a brush to the surface to be silvered. By heating the metal, and subsequent washing, the silvering appears. The application of the paste by means of a brush is chiefly made use of for decorating with silver, articles thinly gilded by dipping. For articles not gilded, the above-mentioned rubbing on of the stiff paste is to be preferred.

Composition of Argentiferous Pastes.—I. Silver in the form of freshly precipitated chloride of silver,* 0.35 oz.; common salt, 0.35 oz.; potash, 0.7 oz.; whiting, 0.52 oz., and water, a sufficient quantity to form the ingredients into a stiff paste.

II. Silver in the form of freshly prepared chloride of silver,* 0.35 oz.; potassium cyanide, 1.05 oz.; sufficient water to dissolve these two ingredients to a clear solution and enough whiting to form the whole into a stiff paste. This paste is also excellent for polishing tarnished silver; it is, however, poisonous.

* From 0.56 oz. of nitrate of silver.

The following composition, which is not poisonous, does excellent service: Silver in the form of chloride of silver, 0.35 oz.; cream of tartar, 0.7 oz.; common salt, 0.7 oz., and sufficient water to form the mixture of the ingredients into a stiff paste.

Graining.—In gilding parts of watches, gold is seldom directly applied upon the copper; there is generally a preliminary operation called graining by which a grained and slightly dead appearance is given to the articles. Marks of the file are obliterated by rubbing upon a whet stone and lastly upon an oil stone. Any oil or grease is removed by boiling the parts for a few minutes in a solution of 10 parts of caustic soda or potash in 100 of water, which should wet them entirely if all the oil has been removed. The articles being threaded upon a brass wire, cleanse them rapidly in the compound acids for a bright lustre and dry them carefully in white wood saw-dust. The pieces are fastened upon the even side of a block of cork by brass pins with flat heads. The parts are then thoroughly rubbed over with a brush, entirely free from grease, and dipped into a paste of water and very fine pumice-stone powder. Move the brush in circles in order not to rub one side more than the other; thoroughly rinse in clean water, and no particle of pumice-stone should remain upon the pieces or the cork. Next place the cork and the pieces in a weak mercurial solution, composed of water, $2\frac{1}{5}$ gallons; nitrate or binoxide of mercury, $1\frac{1}{4}$ oz.; sulphuric acid, $\frac{1}{7}$ oz., which slightly whitens the copper. The pieces are passed quickly through the solution and then rinsed. This operation gives strength to the graining, which, without it, possesses no adherence. The following preparations may be used for graining:

I. Silver in impalpable powder, 2 ozs.; finely pulverized cream of tartar, 20 ozs.; pulverized common salt, 4 lbs.

II. Silver powder, 1 oz.; cream of tartar, 4 to 5 ozs.; common salt, 13 ozs.

III. Silver powder, common salt and cream of tartar, equal parts by weight of each. The mixture of the three ingredients must be thorough and effected at a moderate and protracted heat. The graining is the coarser the more common salt there is in the

mixture, and it is the finer and more condensed as the proportion of cream of tartar is greater, but it is then more difficult to scratch-brush. The silver powder is obtained as follows: Dissolve in a glass or porcelain vessel ⅔ oz. of crystallized nitrate of silver in 2½ gallons of distilled water and place 5 or 6 bands of cleansed copper ¾ inch wide in the solution. These bands should be long enough to allow of a portion being above the liquid. The whole is kept in a dark place and from time to time stirred with the copper bands. This motion is sufficient to loosen the deposited silver and present fresh surfaces to the action of the liquor. When no more silver deposits on the copper the operation is complete, and there remains a blue solution of nitrate of copper. The silver powder is washed by decantation, or upon a filter, until there remains nothing of the copper solution. It is then carefully dried, avoiding all pressure to prevent balling.

Nüremberg Graining Powder is produced by grinding a mixture of honey and silver-foil upon a ground plate-glass with a muller until the proper fineness is obtained. The silver is separated by dissolving the honey in boiling water and washing the deposited metal in a filter until no trace of honey remains. The silver is then carefully dried at a gentle heat.

For the purpose of graining, a thin paste is made of one of the above powders and water and spread by means of a spatula upon the watch parts held upon the cork. The cork itself is placed upon an earthenware dish, to which a rotating movement is imparted by the left hand. An oval brush with close bristles, held in the right hand, rubs the watch parts in every direction but always with a rotatory motion. A new quantity of paste is added two or three times and rubbed in the manner indicated. The more the brush and cork are turned the rounder becomes the grain, which is a good quality; and the more paste added the larger the grain. When the desired grain is obtained the pieces are washed and scratch-brushed. The brushes employed are of brass wires as fine as hair and very stiff and springy. It is necessary to anneal them upon an even fire to different degrees; one soft or half annealed, for the first operation or uncovering the grain; one harder, for bringing

up the lustre; and one very soft or fully annealed, used before gilding for removing any marks which may have been made by the preceding tool and for scratch-brushing after the gilding, which, like the graining, must be done by giving a rotary motion to the tool. If it happens that the same watch part is composed of copper and steel, the latter metal requires to be preserved against the action of the cleansing acids and of the graining mixture by a composition called *resist*. This consists in covering the pinions and other steel parts with a fatty composition which is sufficiently hard to resist the tearing action of the bristle and wire brushes and insoluble in the alkalies of the gilding bath. A good composition is: yellow wax, 2 parts by weight; colophony, 3½; extra fine red sealing-wax, 1⅓; polishing rouge, 1. Melt the colophony and sealing-wax in a porcelain dish upon a water bath and afterwards add the yellow wax. When the whole is thoroughly fluid, gradually add the rouge and stir with a wooden or glass rod. Withdraw the heat, but continue the stirring until the mixture becomes solid, otherwise all the rouge will fall to the bottom. The flat parts to receive this resist are slightly heated and then covered with the mixture, which melts and is easily spread. For covering steel pinions employ a small gouge of copper or brass fixed to a wooden handle. The metallic part of the gouge is heated upon an alcohol lamp, and a small quantity of resist is taken with it. The composition soon melts, and by turning the tool around the steel pinion this becomes coated. Use a scratch-brush with long wires, as their flexibility prevents the removal of the composition. When the resist is to be removed after gilding, place the parts in warm oil or into tepid turpentine, then into a very hot soap-water or alkaline solution, and, lastly, into fresh water. Scratch-brush and dry in warm white wood saw-dust. The holes of the pinions are cleaned and polished with small pieces of very soft white wood, the friction of which is sufficient to restore the primitive lustre. The gilding of parts composed of copper and steel requires the greatest care, as the slightest rust destroys their future usefulness. Should some gold deposit upon the steel it should be removed by rubbing with a piece of wood and impalpable pumice-dust, tin-putty or rouge.

After the parts are grained in the manner described the gilding may be effected in a gold bath composed according to one of the following formulæ: I. Fine gold (as fulminating gold), 1.97 drachms; 98 per cent. potassium cyanide, 5.64 to 8.46 drachms, according to the strength of current used; water, 1 quart. To prepare this bath, dissolve 1.97 drachms of fine gold in aquia regia in a porcelain dish over a gas or spirit flame, and evaporate the solution to dryness. Continue the heating until the solution is thickly fluid and dark brown, and it congeals on cooling to a red-brown laminated mass. Too strong heating is to be avoided, as otherwise the chloride of gold would decompose to metallic gold and escaping chlorine. Dissolve the *neutral* chloride of gold thus formed in 1 pint of water, and add liquid ammonia to the solution as long as a yellowish-brown precipitate is formed, avoiding, however, a considerable excess of ammonia. The precipitate of fulminating gold is filtered off, washed, and dissolved in 1 quart of water containing 8.46 drachms of cyanide of potassium in solution. Boil the solution, constantly replacing the water lost by evaporation until the odor of ammonia, which is liberated by dissolving the fulminating gold in cyanide of potassium, disappears, and then filter. Instead of dissolving the gold itself and preparing neutral chloride of gold by evaporation, it is more convenient to use 3.95 drachms of chemically pure neutral chloride of gold, as furnished by chemical factories, and to precipitate the fulminating gold from its solution.

Too large an excess of cyanide of potassium gives gold deposits of a disagreeable pale color. When working with a strong current the excess of cyanide of potassium need only be small, while with a weak current it may be greater.

For those who prefer to work with gold baths prepared with yellow prussiate of potash instead of potassium cyanide, the following formula is given: II. Yellow prussiate of potash, 8.46 drachms; carbonate of soda, 8.46 drachms; fine gold (as chloride of gold or fulminating gold), 30.86 grains; water, 1 quart. To prepare the bath, heat the solutions of the yellow prussiate of potash and of the carbonate of soda in the water to the boiling-point, add the gold

salt, and boil ¼ hour; or with the use of freshly precipitated fulminating gold, until the odor of ammonia disappears. After cooling, the solution is mixed with a quantity of distilled water corresponding to that lost by evaporation, and filtered. This bath gives a beautiful bright gilding upon all metals, even upon iron and steel. Suitable tension of current, 3.25 to 3 5 volts.

Fulminating gold when dried readily explodes, and hence should not be allowed to dry, but immediately dissolved while in a moist state.

The articles to be gilded are suspended in the bath to metallic holders, connected with the zinc pole of a battery, and of a shape appropriate to the nature and form of the watch parts. One or more platinum wires are used for anodes, and are disposed in the centre or around the bath. The battery most generally employed is composed of three, four, five, or six small Daniell's elements. Those with balloons, on account of their constancy, should be preferred. The slower the gold deposits the finer and more adherent it is. When the coating is sufficient, wash the articles in clear water, and fix again upon the cork, in order to proceed to the last scratch-brushing with a decoction of licorice or of horse-chestnut.

Birmingham Silvering.—The articles are first superficially silvered either by the cold process or by dipping, then immersed in a solution of nitrate of silver, the concentration of which depends on the intended thickness of the coating, and finally heated by the temperature at which the silver salt decomposes, whereby metallic silver remains behind. By these manipulations the articles are prepared for the succeeding operations, which consist in melting in an iron crucible a certain quantity of borax, and heating until the silver melts in it. When this temperature is attained, which is recognized by dipping a small piece of silver into the melted borax, the silvered articles are introduced and rapidly stirred about. The operation is finished when the borax runs freely from one of the articles taken from the bath, and the article itself shows a bright surface. Otherwise the melting is continued, but not to the fusing point of the metallic base. The articles, after being taken from

the bath and allowed to cool off, are boiled in dilute sulphuric acid (1 part acid to 12 water) for the removal of adhering particles of borax, then rinsed in clear water and dried. They finally receive a coating of fine silver in the galvanic way.

Mechanical Silvering According to Bertrand.—The articles of copper or an alloy are first cleansed, and after coating them in the galvanic way with a thin layer of silver, covered with leaf-silver, the firm adherence of which to the metal is then effected by the combined use of heat and a steel brush. The temperature at which the complete adherence of the silver is effected is far below that of the melting-point of silver.

Silvering of Iron According to Rinmann.—The articles to be silvered, for instance, buckles, spurs, etc., are first coated with copper or brass, and the silvering executed upon the smoothed and polished layer of copper or brass. Dissolve 0.58 oz. of silver in aqua regia, and dilute the solution in a porcelain dish with 30 or 40 times the quantity of water. Then pour in as much solution of common salt in water as suffices for the pulverulent precipitation of the silver. Now pour the water off from the silver, and rub the latter into a thin paste with 2.2 ozs. of sal-ammoniac and a like quantity of glass-gall (sandiver). Cover with this paste the brass or copper layer of the iron article, and spread it uniformly with a stiff brush. Both the application of the paste and brushing may be repeated twice or three times. Dry each layer before applying the next by holding the article over a moderate coal fire until it no longer smokes. Then cool the article in a boiled solution of tartar, and brush carefully with a scratch-brush. Finally rinse it off in clean water, dry, rub with the polishing-steel moistened with lime water, and wash again. For dull silvering the operation is the same, but the article is washed in warm water and dried.

To Silver Bessemer Steel and Utensils Manufactured from it.—The articles, etc., are first carefully cleansed with hot lye, then slightly pickled with dilute hydrochloric acid and scoured with fine sand. Now drop solution of mercury in nitric acid into water, slightly acidulated with hydrochloric acid, until a clean strip of copper, when dipped into the mixture, acquires a white coating.

But as iron, unlike other metals, does not amalgamate by mere dipping, it is immersed in the mercury solution, being at the same time in connection with the zinc pole of a Bunsen element, a strip of platinum or gas carbon being used as an anode for the other pole. The metal is soon covered with a layer of mercury, and is then taken out, well washed and silvered in a silver solution. When taken from the silver-bath the article is thoroughly washed and heated over a coal-fire in a fire-place with a good draught until it audibly hisses when touched with the wet finger. It is then allowed to cool, is thoroughly brushed with the scratch-brush, and, if necessary, polished. To save silver the ware may first be covered with a layer of chemically pure tin: 1 part of purified cream of tartar is dissolved in 8 parts of boiling water and one or more tin anodes are connected to the carbon pole of a Bunsen element. The zinc pole communicates with a well-cleansed piece of copper and the battery is made to act until enough tin has deposited on the copper, when this is taken out and the iron ware put in its place. The ware when coated with a layer of chemically pure tin is finally silvered. By the use of alternately suspended strips of alpaca as an anode, the deposit of silver can be somewhat alloyed with the tin. The articles thus produced are considerably cheaper than silvered ware of brass, German silver, etc.

Alloy for Silvering.—This alloy consists of tin, 80 parts; lead, 18; silver, 2; or tin, 90 parts; lead, 9; silver, 1. Melt the tin, and when the bath shows a lustrous white color add the granulated lead and stir the mixture with a pine stick; then add the silver and stir again. Increase the fire for a short time until the surface of the bath assumes a light yellow color, then stir thoroughly and cast the alloy into bars. The operation of silvering is as follows: The article, for instance a knife-blade, is dipped into diluted hydrochloric or sulphuric acid, rinsed in clean water, dried, rubbed with a piece of soft leather or dry sponge, and then exposed in a muffle to a temperature of 158° to 176° F. for five minutes. The effect of this treatment is to render the surface of the iron or steel porous. With iron not very good and coarsely porous the silvering process is difficult to execute. With steel, however, the process is easy;

the article heated to about 140° F. is dipped into the alloy melted in a crucible over a moderate fire. The bath, which must be completely liquid, is stirred with a pine or poplar stick. The surface should show a fine silver-white color. One or two minutes dipping suffices for a knife-blade. When taken from the bath the article is dipped into cold water or, if necessary, hardened and tempered in the usual manner. It is then rubbed dry and polished without heating. Articles thus treated have the appearance of silver, and resist oxidation in the air. To protect them from the action of acid liquids they are first dipped in an amalgam bath of 69 parts mercury, 39 parts tin, and 1 part silver, then while hot in melted silver, and electro-plated with silver. This method of silvering is claimed to be very durable and not costly.

Tin Baths.—Electro-tinning is but seldom executed. A good tin bath is obtained by dissolving 0.35 oz. of pyrophosphate of soda and 15.43 grains of tin salt in 1 quart of water. This bath requires an average current of 2.5 volts tension, cast-zinc plates being used as anodes. Zinc, copper and brass objects are directly tinned in this bath. Iron and steel articles are first coppered or treated with the following composition: Dissolve with the aid of heat, in an enamelled cast-iron vessel, ammonia alum 11 ozs. and fused protochloride of tin ⅓ oz. in 4½ gallons of water. The pieces of iron previously cleansed and rinsed in cold water are immersed in the solution as soon as it boils. They are immediately covered with a film of tin of a fine, white, dead lustre, which may be rendered bright by friction. The bath is maintained at the proper strength by small additions of fused protochloride of tin.

Though the tin bath given above suffices for all cases an alkaline tin bath first proposed by Elsner may be mentioned; its composition is as follows: Crystallized tin salt, 7 ozs.; water, 1 quart; and sufficient potash lye of 10° Bé. to dissolve the precipitate formed. The solution of the tin salt in the water is mixed with potash lye of the stated concentration until the precipitate of zinc hydrate which is formed is redissolved; some electro-platers recommend the addition of 0.35 oz. of potassium cyanide to the bath. With-

out this addition the bath requires 3.75 to 4 volts, and, with it, 3.5.

Tin baths must not be used at a temperature below 68° F.; they require according to their composition a current of 2 to 3 volts. Too strong a current causes a pulverulent separation of the tin which does not adhere well.

Tinning by Contact.—Suitable solutions for tinning by contact with zinc in the boiling tin bath are as follows:

I. Pulverized tartar, 3.52 ozs.; alum, 3.52 ozs.; fused protochloride of tin, 14.11 drachms; rain-water, 10 quarts.

II. Potassium pyrophosphate, 7 ozs.; crystallized protochloride of tin, 0.7 oz.; fused protochloride of tin, 2.82 ozs.; water, 10 quarts.

III. *For Tinning by Dipping.*—Potassium pyrophosphate, 5.64 ozs.; fused protochloride of tin, 1.23 oz.; rain-water, 10 quarts.

Formula I. and II. yield good results. To tin by contact, heat the bath to boiling and suspend the clean and pickled articles in contact with pieces of zinc, or better, wrapped around with zinc-wire spirals, care being had to from time to time move them about to prevent staining. Large baths which cannot be readily heated are worked cold, the articles being covered with a large zinc plate; in the cold bath the formation of the tin deposit requires, of course, a longer time. By using a galvanic current the deposit can be made as heavy as desired. By dipping in the bath prepared according to formula III., zinc can only be coated with a very thin film of tin, which, however, can be made as thick as desired by the use of a battery.

For thinning by contact in a cold bath, Zilken has patented the following solution: Dissolve in 100 quarts of warm water, tin salt, 7 to 10.5 ozs.; pulverized alum, 10.5 ozs.; common salt, 15.87 ozs.; and pulverized tartar, 7 ozs. The cold solution forms the tin bath. The articles to be tinned are to be wrapped round with strips of zinc. Duration of the process, 8 to 10 hours.

Tinning by Boiling Articles of Iron and Steel.—Crystallized ammonium-alum, 7 ozs.; crystallized protochloride of tin, 2.82 drachms; fused protochloride of tin, 2.82 drachms; rain water,

10 quarts. Dissolve the ammonium-alum in the hot water, and when dissolved add the tin salts. The bath is to be used boiling-hot, and kept at its original strength by an occasional addition of tin salt. The clean and pickled iron articles being immersed in the bath become, in a few seconds, coated with a firmly adhering film of tin of a dead-white color, which may be polished by scratch-brushing or scouring with saw-dust in the polishing drum. Tinning by boiling in the bath, composed as above given, is the most suitable preparation for iron and steel articles which are to be subsequently strongly tinned by the galvanic process. To be entirely sure of success it is recommended to thoroughly scratch-brush the articles after boiling, to replace them in the bath, and then suspend them in a bath composed of crystallized sodium pyrophosphate, 3.52 ozs.; fused tin salt, 0.35 oz.; and water, 10 quarts. To prepare the bath dissolve the sodium pyrophosphate in the water, suspend the tin salt in a small linen bag in the bath, and move the bag to and fro until its entire contents are dissolved.

Another Very Suitable Bath is as follows: 98 per cent. cyanide of potassium, 3.52 ozs.; potassium carbonate, 35.27 ozs.; protochloride of tin, 14.11 drachms; water, 10 quarts.

To Tin Small Brass or Copper Objects.—Prepare a bath from pulverized tartar, 3.52 ozs.; protochloride of tin, 14.11 drachms; water, 10 quarts; and, after heating the bath to boiling, immerse the objects to be tinned (pins, hooks, handles, eyes, etc.) in a tin sieve or in contact with a piece of zinc; frequent stirring with a tin rod shortens the process.

Another Method, given by Böttger, gives good results. Dissolve oxide of tin by boiling with potash lye, and place the copper or brass objects in the boiling solution in contact with tin shavings.

Elsner's Bath yields equally good results. It consists of a solution of equal parts of tin salt and common salt in rain water. The manipulation is the same as given above.

Stolba's Method of Tinning.—Prepare a solution of 1.76 oz. of tin salt and 5.64 drachms of pulverized tartar in 1 quart of water, moisten with this solution a small sponge, and dip the latter into pulverulent zinc. By then rubbing the thoroughly cleansed and

pickled articles with the sponge they immediately become coated with a film of tin. To obtain uniform tinning the sponge must be repeatedly dipped, now into the tin solution, and now in the zinc powder, and the rubbing continued for a few minutes.

Cold Tinning.—Block tin dissolved in hydrochloric acid with a little mercury forms a very good amalgam for cold tinning; *or*, 1 part of tin, 2 of zinc and 6 of mercury. Mix tin and mercury together until they form a soft paste. Clean the metal to be tinned, being careful to free it from greasiness. Then rub with a piece of cloth moistened with hydrochloric acid, and immediately apply a little of the amalgam to the surface, rubbing it with the same rag. The amalgam will adhere to the surface and thoroughly tin it. Cast-iron, wrought-iron, steel and copper may be tinned in this way. Those who find it difficult to make soft solder adhere to iron with sal-ammoniac, will find no difficulty if they first tin the surfaces in this manner and then proceed as with ordinary tin-plate.

Tinning Hard Steel or Case-hardened Articles.—In the first place a bath of melted tin will not injure the temper or materially soften hardened steel surfaces, inasmuch as tin melts at 442° F., and polished steel acquires a straw color at 460° F. The iron or steel articles must first be freed from scale (if any), either from the foundry or forge, by means of a pickle of dilute sulphuric acid, and then scratch-brushed or scoured with sand. If the articles are of steel and have been quenched or hardened in oil, every trace of the oil must be removed by immersion in boiling soda lye; next the surface must be made chemically clean; even the film of oxide, due to a pale straw color, will prevent the due adherence of the tin to the steel. Have a bath consisting of 1 part of hydrochloric acid to about 20 parts of water, hold the article with a pair of brazing tongs and stir it for a few seconds in the bath, withdraw it, and, while still wet, instantly immerse it in a ladleful of melted tin, the surface of which should be kept from oxidizing by a flush of good clean tallow. In less than half a minute the article, when withdrawn, will be found completely

tinned. Of course precaution must be taken not to overheat the tin, but keep it down to the proper melting temperature.

Improved Process of Tinning Metals.—An improved process for coating metals with tin, by Borthel and Moller, of Hamburg, is said to possess the advantage of preventing, or at least delaying, oxidation. The process can be employed with special advantage for tinning cast-iron cooking utensils, household and other implements of cast-iron, as the employment of poisonous enamel is avoided and a much higher degree of polish attained. The process can also be employed for protecting architectural or other iron decorations from rusting by the coating of tin or of another metal without detriment to the sharpness of the form, as is the case with the customary oil or bronze paints. In order to produce a perfectly even coating of tin on cast-iron, the latter is first provided with a thin coating of chemically pure iron, regardless of the form of the casting. This coating is produced in a galvanic manner in a bath composed as follows: 21.16 ozs. of sulphate of iron, Fe S O, are dissolved in 5 quarts of water, to which is added a solution of about 84.72 ozs. of carbonate of soda, Na C O, in 5 quarts of water. The resulting precipitate of ferrocarbonate is dissolved in small quantities in concentrated sulphuric acid until the fluid has a green color. The bath is then rendered aqueous by adding about 20 quarts of water. Blue litmus paper dipped in the bath must assume a deep claret color, and red litmus paper remain unchanged.

The objects to be provided with a coating of chemically pure iron are placed in the bath opposite to the anode of cast or wrought-iron, and both parts connected to the corresponding poles of a dynamo-machine, electric battery or other appropriate source of electricity. In a very short time the objects placed in the bath are covered with a coating of iron, the thickness of which depends on the duration of the action of the bath or the strength of electric current. The coated objects are then well rinsed in clean water, dried, then painted with, or immersed in, a solution of ammonia in chloride of zinc, or chloride of zinc alone, and then immersed in a vessel containing melted tin. The tin adheres with great tenacity to the prepared surface, and the surplus of tin can be

readily removed by a brush or in another manner. If the object to be tinned is of such size, or so complicated in form that it cannot be readily immersed in molten tin, it can be placed in a galvanic tin bath, which can be readily made into any desired size. In this bath it is provided with a layer of tin of desired thickness, which, after having been painted either with a solution of chloride of zinc, or of ammonia in chloride of zinc, can be heated to such a degree that the tin is uniformly melted on to the object.

In like manner objects cast or made of lead, or other readily melting metals which would lose their form by melting when immersed in melted tin, are, previous to tinning, provided with a coating of tin in a galvanic bath, as mentioned above, without being subjected to heat for melting the layer of tin deposited on the same. With objects of wrought or rolled iron, or which do not require the before described treatment, *i. e.*, the production of a coating of chemically pure iron, it will be sufficient to carefully clean the same and paint them with a solution of ammonia in chloride of zinc, or a concentrated solution of chloride of zinc. This tinning process combines the advantage of simple manipulation and great durability of the coating with cheapness of manufacture, which is partially attained in the saving of tin.

To Tin Kettles.—The kettle to be tinned is first freed from oxide, etc. It is then coated with a 10 per cent. solution of chloride of tin, to which as much purified tartar as will lay upon the point of a knife has been added. Now rub thoroughly the moistened places with coarse zinc powder, obtained by pulverizing zinc just congealed. This process may be used for brass, cast and wrought-iron, and also for steel. The tinning, to be sure, is thin, but it adheres firmly, and a thicker coat can be obtained by repeating the process after a few minutes. Finally the kettle is rinsed off and polished in the usual manner, for instance, with whiting.

To Tin Lead Plates.—Heat the plates to the melting point of tin, next scatter powdered colophony upon them, then pour melted tin over them and spread out and rub on both the colophony and tin with tow; finally wipe off the excess of tin. Lead

plates tinned in this manner on one or both sides can be rolled out as desired.

To Prepare Tinned Lead Pipes.—According to Grand's method for the manufacture of such pipes, a cylindrical mould with a hollow pivot is placed horizontally upon a lathe or other machine which will give it a quick, revolving motion. As much melted lead as is necessary for lining the interior surface with a sufficient thickness is then introduced through the above-mentioned hollow pivot. The machine is now set in rapid motion, and the melted metal is forced by centrifugal force against the inner surface of the mould, forming a hollow cylinder of uniform thickness. Through the same pivot a corresponding quantity of melted tin is then introduced, which by reason of the constant revolution deposits itself firmly upon the inner surface of the previously formed cylinder of lead. The tube thus made can be drawn out in the usual manner.

To Make "Fonte Argentine," or Tinned Cast-iron.—Dissolve in 250 quarts of water 6.6 lbs. of sodium pyrophosphate, and add 1.1 lb. of ordinary and 1.65 lb. of dried and fused tin-salt. Heat the whole to 176° F., and place in it the iron articles, together with a few pieces of tin. In working on a large scale, the fluid and the articles to be tinned are brought into large vats provided with an axis, which can be set in motion by a suitable mechanism.

Zinc Baths.—The deposition of zinc in a galvanic way being connected with certain difficulties, it is but little applied in practice, and, hence, only the compositions of a few baths, which yield the best results, are given.

I. Dissolve 2 ozs. of caustic potash in 1 pint of water, add to the solution one of 0.35 oz. of chloride of zinc and 0.7 oz. of sal-ammoniac in 1 pint of water, and stir until the precipitate at first formed is redissolved. Rolled sheets of zinc are used as anodes, and a current of a tension of about 3 volts is required. The articles to be zinced must be frequently moved about, as the zinc has a tendency to deposit only upon the portion nearest to the anodes, and, furthermore, they must be frequently scratch-brushed and replaced in the bath. It is advisable to warm the bath.

II. Alum, 3½ ozs.; zinc oxyhydrate, 0.35 oz.; water, 1 quart. Dissolve 0.8 oz. of sulphate of zinc in 1 pint of water, and carefully add potash lye until a further drop of it produces no longer a precipitate; an excess of potash lye must be avoided, as it dissolves the zinc oxyhydrate. The precipitate is filtered off, washed with water, and the moist zinc oxyhydrate mixed with the solution of the alum in the water, whereby it becomes completely dissolved. This bath requires a tension of current of from 3 to 3.5 volts.

III. Sulphate of zinc, 2¾ ozs.; water, 1 quart; and potash lye sufficient to redissolve the precipitated zinc oxyhydrate. This bath also works quite well, and requires from 2.75 to 3 volts, and 1.5 ampères per 15½ square inches.

To Zinc Copper and Brass Without a Battery.—Pour over finely granulated zinc or zinc-dust in a porcelain or other non-metallic vessel a concentrated solution of sal-ammoniac and heat to the boiling point. Pickle the articles to be zincked with somewhat dilute hydrochloric acid and throw them into the boiling solution. By continued boiling the articles become in a short time coated with a very bright layer of zinc. Finely granulated zinc is obtained by pouring the melted metal into a strongly heated iron mortar, and thoroughly and quickly rubbing the fluid mass with the iron pestle until it congeals.

Another Process is as follows: Commercial zinc gray, *i. e.*, very finely divided metallic zinc, is boiled several hours with a concentrated solution of caustic soda. The articles to be zincked are then immersed in the boiling fluid, and, the boiling being continued, become in a short time coated with a very bright layer of zinc. When a copper article thus coated with zinc is carefully heated in an oil bath to between 248° and 284° F., the zinc alloys with the copper, forming a sort of bronze similar in color to tombac.

To Zinc Iron in the Cold Way.—This process may be used to protect iron from rust. A mixture of finely pulverized zinc with oil and a siccative is applied with an ordinary brush, one application being, as a rule, sufficient. Coating the article twice insures, it is claimed, complete immunity from the effects of sea-water and

the atmosphere. The coating of zinc gives to the iron a steel-gray color, and does not prevent the application of other paint.

Galvanizing Sheet-iron.—The metal to be coated requires to be freed from oxide and impurities of every description before it will take a proper coating of zinc. The preliminary cleaning, however, does not require to be done with such extreme care as in the case of galvanoplastic deposits. The first step in the process is, therefore, the operation of pickling, *i. e.*, the removal of the black scale. For this operation there is usually provided a stout rectangular wooden tank, from 5 to 6 feet high and 9 to 10 feet long, and wide enough to accommodate from 100 to 200 sheets at a time. This contains the pickling liquid, generally commercial sulphuric acid diluted with from 10 to 12 parts of water; and into this liquid, heated by steam, as many sheets are immersed (on edge) as the tank will accommodate. In from 1 to 2 hours the scaling of the iron is effected, a workman or two all this time industriously wedging the individual sheets apart with suitably contrived tongs to insure the penetration of the pickle to all the sheets. This done the sheets are withdrawn from the pickle tank and transferred to large, shallow washing vats of wood, in which they are washed in a stream of fresh water. They are next subjected to an inspection in order that any obstinately adhering particles of scale or cinders that the acid may have failed to take off may be removed. For this purpose they are passed, one by one, to a bench or table where a workman armed with a stiff brush and a triangular-shaped steel scraper carefully examines each sheet, and removes such patches of scale as may yet adhere in spots upon the pickled sheet. From his hands they pass into a second shallow tank filled with clean water (which should properly be renewed from time to time) and in which they are allowed to remain for 12 to 24 hours. The purpose of this washing is to remove all traces of sulphuric acid and basic sulphate of iron from the pickled sheet, the retention of which would otherwise act injuriously upon the character and the durability of the zinc coating. In order that the work may go on continuously, several of such water-tanks must be provided, so that a lot of iron shall always be ready for the next operation. This is termed

"clearing," and consists in immersing the sheets from the water-tanks for a few minutes in commercial hydrochloric acid contained in a flat wooden tank like the water-tanks above described. This treatment removes every trace of oxide from the sensitive iron skin, forms a thin layer of chloride upon it, and renders the iron insensible to oxidizing influences during its subsequent manipulation. From the clearing tank the sheets are arranged on edge in a rack to keep them from touching each other (which rack is commonly mounted on a truck) and rolled twenty-five or more at a time into a drying chamber. In about 20 minutes or half an hour they are removed and are then ready for dipping. The galvanizing pot for sheet-iron work is a rectangular vessel of heavy boiler plate, riveted in the most substantial manner, about 4 feet deep and 12 feet long and 15 to 24 inches wide and capable of containing 20 to 30 tons of zinc. Its bottom rests upon solid masonry, the brick-work being carried up about it on all sides, providing a fire space all about the sides of the pot, by which the metal is kept in a melted state, and its temperature regulated to a nicety with the aid of draft spaces opened or closed by removing or inserting bricks provided for the purpose. The temperature of the zinc bath is a matter of vital importance to the quality of the work and of great economical importance, and it is here that the skill and experience of the workman tells strongly. For sheet-iron work the heat of the bath is kept at about 1000° F.

The zinc being of the right heat, a thin centre-plate of iron is put in position, its edge dipping slightly beneath the surface of the zinc, and dividing the bath longitudinally into two parts. The object of this contrivance is to insure that the sheets when dipped and passed to the other side of the bath shall be completely immersed in the melted metal. This object is also accomplished by drawing the sheets through the bath by means of a pair of rollers submerged in the melted metal. They are passed one by one into the metal, guided beneath the centre-plate, and, as they emerge on the other side, seized at one end by an iron gripper and drawn through a layer of sand strewn on the surface of the metal, the object of which is to remove all the superfluous metal. The

operations of dipping and drawing proceed at about the rate of one sheet per minute. In the setting of the zinc coating, which takes place almost instantly after the withdrawal of the sheet from the bath, the beautiful crystallization of the metal ensues, which is so much admired. This appearance is known to the trade as spangling, and much attention is given to the preliminary preparation of the iron just described, upon the proper performance of which the size and beauty of the spangles are largely dependent.

From time to time, as the sheets are dipped, a handful of sal-ammoniac is strewn upon the surface of the metal bath for the purpose of clearing it of oxide and insuring a perfect contact of the clean metals with each other. Sometimes the centre-plate and sand are dispensed with, and the sheets are "dipped bright." From the bath the sheets pass to the rolls to be straightened; next they are bundled, then weighed and stamped, and are now ready for shipment or use.

With cast-iron and general jobbing work the process is substantially the same. Owing to its greater impurity, however, objects of cast-iron require a much longer period of immersion in the metal than sheet, which, as stated above, takes the coating instantly. Some time, too, is required with large and heavy castings before they become heated to the temperature of the zinc bath, which is necessary before the amalgamation will ensue. Castings require on these accounts an immersion of from 15 to 30 minutes. Where small castings can be "tumbled," and thus deprived of much of their adhering scale and sand, it is frequently unnecessary to pickle them in the manner here described. In such cases they are simply cleaned by a few minutes' immersion in hydrochloric acid and dipped. On the other hand, common rough and unfaced castings require much time and attention to scale and prepare them for the zinc bath. Where the articles are small enough a lot of them is placed in a perforated iron ladle with a long handle and dipped, with occasional shaking, until they have taken a proper coating. They are then removed from the ladle singly with tongs, the surplus metal being knocked off as they are taken out. Hoop iron and wire are passed through the zinc from a reel at a uniform

speed. Wire cloth is beaten as it comes out to remove the superfluous metal that would otherwise clog up the meshes.

A matter which seriously troubles the galvanizer, and which entails considerable pecuniary loss on him, is the formation of what is technically known as dross. This is an alloy of zinc and iron which is formed in the zinc bath, partly by the solvent action of the zinc on the iron of the pot, but chiefly from the iron articles dipped and from the dripping off of the superfluous amalgam as they come from the bath. This alloy carries from 90 to 95 per cent. of zinc and from 5 to 10 per cent. of iron and other impurities. It has a higher point of fusion and a higher specific gravity than zinc; hence, as it is formed, it gradually forms a mushy, more or less granular, accumulation in the bath. While the work is going on the agitation of the metal stirs up the accumulated dross and keeps it floating through the liquid zinc, and as it greatly interferes with the smoothness of the work it must be removed from time to time. This operation, called "drossing," is performed with a large perforated iron ladle, through the openings of which the fluid zinc runs off, while the dross is retained, packed into moulds, so as to form slabs of about 75 lbs. weight, and in this form is usually sold to the smelters and refiners, who regain the zinc it contains either by distillation or by special patented procedures. The formation of this dross is a serious item of loss, amounting in some establishments to as much as 30 per cent. of the whole amount of zinc used, though, on the average, it will not exceed 25 per cent.

The simplest method for treating this alloy, by which much of the zinc it carries may be gained, consists in melting it in a separate iron pot and allowing it to cool slowly and without disturbance. The upper layers of the metal, which may be skimmed off, will be found to consist of nearly pure zinc. In this manner a large quantity of metal may be regained from the dross and used again. The bottoms, rich in iron, may be disposed of to the refiners.

To prevent the adhesion of the dross to the bottom of the pot, as well as to facilitate its removal therefrom, in the manner above described, it is customary to introduce a small quantity of lead into the zinc bath. This metal does not alloy with zinc or iron, and by

reason of its greater density it sinks to the bottom of the pot, forming a liquid cushion on which the dross and other impurities float. To lend additional whiteness to these galvanized wares some operators introduce from time to time a small quantity of tin.

The spent "pickle" (sulphuric acid) is collected in large vats and disposed of to the manufacturers of sulphate of iron (green vitriol).

To Galvanize Old and New Parts.—Galvanized articles subject to strong wear frequently become damaged. To put them into good condition, *i. e.*, to regalvanize them, it is necessary to first thoroughly clean them. With iron articles the process is as follows: Place the articles in a pickle composed of 5 to 8 drachms of sulphuric acid to 1 quart of water, allowing them to remain until the oxide is eaten off. Then dip them, but only for a moment, in strong nitric acid, and wash off quickly with much water. To large articles the pickle may be applied with a brush, thoroughly scrubbing afterward with sand. This scrubbing is also necessary when the coating of zinc still adheres to some places or parts of the articles, since the zinc strongly oxidizes in this pickle. Articles of brass or copper are best cleansed with a pickle consisting of equal parts of sulphuric and nitric acids with a small addition of common salt. If the articles are strongly oxidized or greasy it is best to previously pickle them and remove the grease by heating. The pickle for this purpose consists of 1 part sulphuric acid in 8 to 10 water. The articles being thus thoroughly cleaned may be regalvanized in various ways. Iron is best galvanized by dipping into a fluid zinc bath. The articles are first dipped in a concentrated solution of sal-ammoniac, then quickly dried and finally immersed in the melted zinc. Articles of large size must not be too quickly removed from the bath, as otherwise the zinc adheres more firmly to places not yet sufficiently heated than to others. To prevent the articles from cooling off too quickly they must, after being removed from the zinc bath, be placed in hot, preferably boiling, water. Small articles are brought into the zinc bath in a net of strong iron wire and have to be constantly shaken to insure all the places and all the articles being coated with zinc. Copper and brass may also be coated with zinc by chemical

means, the process being as follows: The articles are dipped into a bath of chloride of zinc solution made boiling hot and to which a few pieces of granulated zinc are added. By remaining a few minutes in contact with the zinc the articles become coated with a very bright, firmly-adhering layer. The articles may also be dipped in a solution of zinc dust in concentrated caustic lye. This bath must also be brought to the boiling point.

Metallic Coating upon Flowers and Insects by the Galvanic Way.—The process consists in first dipping the articles into an albuminous fluid in order to prevent their metallization. They are then immersed in a bath of a 20 per cent. nitrate of silver solution, and exposed to the action of sulphuretted hydrogen to reduce the adhering nitrate of silver. The organic substance is now ready for the galvanic deposit; by the latter the smallest inequalities of surface become apparent, and small hairs scarcely visible to the naked eye can be plainly distinguished.

To Coat Iron Articles with Other Metals, According to Newton.—According to this process the articles are not prepared, as is generally customary, by treating them with dilute acid, but by dipping in ordinary concentrated hydrochloric acid as found in commerce, whereby the time required for cleaning the articles is much shortened. After sufficient action of the acid, a few pieces of zinc are dropped into the bath between the iron articles; the action of the acid upon the iron ceases immediately, because it attacks and dissolves the zinc. About 1 lb. of zinc suffices for half a ton or more of iron bolts or nails. Articles not very rusty or dirty are cleaned in a minute or less. The articles when taken from the acid are immediately immersed, without previous washing or drying, in the melted metal, care being, however, had to introduce them gradually to prevent the scattering of melted metal. The union of the metal with the iron by this process takes place with greater ease and more completely than when the articles are previously dried and exposed to the air. The kind of metal to be used for coating the iron depends on the intended use of the article. Two alloys rich in lead are, however, proposed, because for certain purposes, for instance, for ships' sheathing and covering roofs, lead protects better than

tin. For example: Tin, 15 parts; lead, 75; copper, 5; and antimony, 5; *or*, tin, 15 parts; and lead, 85. The antimony effects a more complete union of the tin and lead, and without antimony the copper appears only mechanically mixed with the lead. This alloy gives as white a coating as tin alone, the bluish color of the lead being neutralized by the copper and antimony.

XII.

FLUXES AND LUTES.

Fluxes.—There are numerous substances which, being themselves easily fused, are added to more refractory materials to promote their fusion; the following articles are largely used for this purpose: Crude tartar, commercial cream of tartar, borax, saltpetre, sal-ammoniac, common salt, limestone, glass, and fluor-spar.

As most metals are more disposed to oxidize when in a molten state than when solid, it is usual to cover the surface of the metal in the crucible or melting-pot with some flux, to protect the metal from the action of the air. In the cupola the slag from the lime answers this purpose. With the precious metals powdered charcoal is frequently used, as are also borax and saltpetre. Brass founders employ broken glass or powdered charcoal. For the more fusible metals resin and oils are used.

The best flux for alloys of copper and tin is resin. It should be added when the metals are almost melted. In using this flux the copper is usually melted first and the flux added. When it is in the mushy state, after the flux has been put in, the zinc and tin are added. A good flux for old brass is common resin soap. It should be added in small lumps, and stirred down into the metal when in the molten state. In forming alloys of different metals, the molten metals should always be kept under a covering of black glass or pulverized charcoal to prevent oxidation.

Black Flux, as it is commonly called, is composed of 7 parts of

crude tartar, 6 of saltpetre, 2 of common bottle glass, and by some a small amount of calcined borax is added. These ingredients are first finely powdered and mixed, and then gradually heated in an iron pot or ladle, so as to burn them together. Care should be taken not to overheat the mixture, and as soon as thoroughly melted and mixed together it should be removed from the fire and allowed to cool. After it has cooled it is finely pulverized and sifted, and is then ready for use. It has a great affinity for moisture, and should be protected against it by being placed in glass bottles, and the bottles corked up until wanted for use. This is the most powerful flux that can be made. It is but little employed in forming or fluxing alloys, but principally by assayers in assaying different kinds of metallic ores. In these assays the quantity of black flux used varies according to the qualities of ores, but the amount is generally about equal proportions of ore and flux. The ore is first roasted, and then finely broken up and mixed with the flux, and the whole is then rapidly heated in a crucible. If the flux does not make the slag sufficiently fluid to allow the metal to settle, a small amount of calcined borax is added, which makes the slag more liquid, and permits the metal to pass to the bottom of the crucible. The crucible is then removed from the fire, and the mixture is either poured from it or allowed to cool in it. After it has cooled the slag is knocked off with a hammer, and a bottom of metal is obtained. When using this flux the clay crucible, without either clay or graphite, is preferred, for the flux is very hard on a crucible that contains either of these substances. Black flux is used by some foundrymen in melting the fine scrap sweepings from the floor, and dross and refuse from the crucible. By melting these in a crucible with black flux they obtain considerable amounts of metal from them that would otherwise be lost. In melting the refuse with black flux the common clay crucible should always be used.

Gray Flux is a product of the decrepitation of 3 parts of tartar and 2 of saltpetre and contains considerable less carbon than the black flux.

White Flux is obtained by the decrepitation of 1 part of crude

tartar and 1 to 2 parts of saltpetre. It contains chiefly potassium carbonate besides potassium nitrate, next small quantities of calcium carbonate (from the content of lime in the crude tartar), some metallic chlorides and sulphates. On account of its content of nitrates it is chiefly used as an oxidizing flux. The mixture is the more effective the more complete the mixture of tartar and saltpetre. It has great affinity for moisture and must be kept in well-closed bottles.

Quick Flux is a mixture given by Beaumé. It consists of saltpetre, 3 parts; sulphur, 1, and saw-dust (from resinous wood), 1. It promotes the fusing of metals which can be readily converted into sulphides (copper, silver) by converting them into readily fusible sulphides.

Flux for Reducing Arsenic.—Carbonate of soda, in crystals, 8 parts; finely powdered charcoal, 1 part. Heat gradually to a red heat.

Cornish Reducing Flux.—Crude tartar, 10 parts; saltpetre, 4; borax, 3. Powder together.

Refining Flux.—Crude tartar and saltpetre, equal parts. Burn together.

Crude Flux.—Saltpetre, 1 part; cream of tartar, 2 parts. Mix with finely powdered charcoal; keep dry in an air-tight vessel or well cork the bottle.

Fluxes for Arsenical Compounds.—I. Dry potassium carbonate, 3 parts; cyanide of potassium, 1 part.

II. Dry carbonate of soda and potassium cyanide, equal parts.

Moreau's Reducing Flux.—Powdered glass, free from lead, 8 parts, and 1 part each of calcined borax and charcoal. Powder well and mix.

Salt Cake.—In smelting expensive articles the use of salt cake as a flux greatly improves the appearance of the metal or alloy; the refuse uniting with the salt cake floats to the surface of the crucible and is skimmed off.

Lutes.—These are soft adhesive substances, generally of an earthy composition, used for *closing* vessels to make them air and gas tight, or for *coating* over vessels or parts of vessels, to protect them from the effects of high temperatures.

Stourbridge Clay in fine powder, made into a paste with water, will sustain a great heat.

Windsor Loam, a natural mixture of sand and clay.

Either of the above may be used for coating vessels or for making tight the hot joints of metallic vessels. Mixtures of pulverized borax with either of the above, or with common clay, form fusible fluxes, useful for glazing over the surfaces of vessels so as to close their pores.

I. Mix thoroughly 2 parts good clay, 8 parts sharp washed sand and 1 part horse dung; then temper like mortar.

II. Linseed or almond meal mixed to a paste with milk, lime water or starch paste. This lute stands a temperature of 500° F.

Fat Lutes.—I. Mix dry clay or pipe-clay in powder with drying linseed oil into a thick paste. The part to which this is applied must be clean and dry.

II. Plaster of Paris mixed with water, milk or weak glue. Both these lutes stand a dull red heat.

White-lead, paste and paper, caoutchouc and yellow wax are also used as lutes for various purposes.

XIII.

LACQUERS, PAINTS AND VARNISHES.

Japanning Tin.—The first process with the tea-tray, which is made of sheet-iron, is to scour it well with a piece of sandstone, which process removes all the scales of iron, and makes the surface perfectly smooth. It is then given a coat of vegetable black, which must be mixed with black tar varnish, and thinned with tar spirits and well strained; only a small quantity of varnish is necessary, as this coat may dry dead. The article is then put into a stove to harden. The stove is nothing more nor less than a large oven; large of course where a great quantity of work is put in at one time. The heat must be as even as possible all over the heated space, and must be free from dust. The temperature must not be much, if

any, under 212° F., the articles to remain in this temperature 10 to 12 hours. When taken out of the stove they are allowed to get cold. They then receive a coat of black tar varnish, which must not be thinned, except it be so thick as to be quite unworkable, and in that case tar spirits should be used sparingly. A stiffish bristle brush with short bristles should be employed. The varnish is distributed evenly all over the surface, and must be put on so sparingly that it cannot "run," as japanners say, which it is sure to do immediately it gets warm, particularly on upright articles, if too much is put on. Two coats of this varnish on the top of the vegetable black are frequently sufficient when done by an expert hand, but a third coat improves the work, and often is indispensable; 10 to 12 hours' hardening is requisite between the coats. It is likewise necessary to rub down the small lumps which will appear after each coat, with a piece of pumice, first made flat by rubbing it on a slab of slate. Keep dipping the pumice in water. This rubbing down must be executed very lightly, or the smooth parts will be scratched. If the article is to be decorated with burnished gold, the first process after coming out of the stove the last time is to "rough" it. This is done with very fine pumice sand applied with some kind of corded or roughish material, jean being the material most used. The process is very laborious, as it requires all the pressure that can be employed, and that, too, for some considerable time. It is part of the polishing. When the surface has been made level by this, the next thing is to go through the same again; but this time, instead of using sand and the cutting material, black or soft rotten-stone must be employed, with flannel or cloth kept well wetted. This makes the surface exceedingly smooth, and ready to be brightened up into a fine polish by rubbing the sand up and down. The workman so employed has to keep rubbing the dry hand into powdered white rotten-stone, also occasionally moistening the hand by placing it on a wet cloth for the purpose. The polish soon comes up under a practical hand. It takes months of practice in this polishing before the hand obeys the intellect. The work now passes to the ornamenter. After he has put on his ornaments of gold and color, it is placed in a stove

at only a few degrees of heat, as much heat would destroy his work. When dry, that part only of the article which is covered with ornament receives a coat of copal polishing varnish. This varnish does not improve the appearance, but is necessary to preserve the decoration. No polish or varnish can equal black varnish, which is about a fourth the price of copal. This varnish is put on with a flat camel-hair brush, and will harden in a heat of about 100° F. in 4 hours. If put in too great a heat it will turn color and completely spoil the work. It is now ready for "finish" polishing, which consists of the rotten-stone process again and handing up as before, and last of all, a few drops of oil are used with a sprinkling of water, and this is called oiling off. It requires great dexterity, or, instead of adding to the lustre with the oil, it will completely dull the surface. There are plenty of goods that do not go through all these processes, and yet look fairly well; such, for instance, as grocers' canisters, and numerous other articles. These, as soon as they have received the second coat of black varnish, are taken directly to the ornamenter without being "roughed" or polished, and if the varnish has been put on well and kept free from dust, they look very well. When no polishing is done either before or after the ornamenting, the article is frequently covered all over with the copal varnish coat. The only safe way of obtaining the proper varnishes is to get them from those who supply japanners.

When tin goods are to be japanned the only preparation necessary is to clean off all grease spots with a piece of clean rag dipped in turpentine; and as to heat, when it is not too hot to disturb the solder, it will not hurt the black varnish, providing it is put on sparingly. If not the varnish will shrivel. The finish upon grocers' canisters may be readily obtained, as there is nothing on them but good stoving and varnishing—no polishing. *Colored surfaces* are ground in turpentine in a mill, or on a stone slab, and mixed with mixing varnish. If an *emerald green ground* is required, some let the first coat be of white-lead mixed with varnish, and this is followed by two coats of the emerald green without any white in it. The coat of white gives to the green a solidity which could not be obtained otherwise. A moderate heat is required as

these varnishes will not become hard without heat, but in no comparison to the heat nor the time required for black varnish.

A Vermilion Ground is sometimes first coated with orange-red, and one coat of vermilion on that should be sufficient. When the last coat is dry or hard the whole surface should be well rubbed down with fine pumice sand, which can be purchased from oil and paint shops; but it must be fine, and, if necessary, dusted through fine muslin. What is called a "bob" must be made of a piece of jean, large enough to hold in the hand conveniently, and this must be dipped into water and then into the sand; this rubbed vigorously up and down the work will make it quite smooth. Use freely of the water, but moderately of the sand. Afterwards wipe off all cleanly with a wash-bather, and the surface will be found to be dull, but smooth. Exactly this method is also used for black varnished surfaces. The work is now ready for ornamenting, if any ornamenting is to be done; if not, it is ready for varnishing with the clear varnish, which will at once brighten the surface which had to be dulled in the operation of smoothing it.

Black Grounds for Japanning.—I. Asphalt, 1 lb.; copaiba balsam, 1 lb., and a sufficient quantity of oil of turpentine. The asphalt is melted over a fire, and the balsam, previously heated, is mixed in with it. The mixture is then removed from the fire and mixed with the turpentine.

II. Moisten good lampblack with oil of turpentine and grind it very fine with a muller on a stone plate, then add a sufficient quantity of ordinary copal varnish and rub well together.

III. Asphalt, 3 ozs.; boiled linseed oil, 4 quarts; burnt umber, 8 ozs.; and a sufficient quantity of oil of turpentine. Melt the asphaltum, stir in the oil, previously heated, then the umber, and, when cooling, thin down with the oil of turpentine.

IV. An extra fine black is prepared from amber, 12 ozs.; purified asphalt, 2 ozs.; boiled linseed oil, ½ pint; resin, 2 ozs.; oil of turpentine, 16 ozs. Fuse the gum, resin and asphalt, add the hot oil, stir well together, and, when cooling, add the turpentine.

Black Japan for Tin Lanterns.—Asphalt, 1½ ozs.; boiled lin-

seed oil, 4 pints; burnt umber, 4 ozs. Heat till well mixed, and, when cool, add turpentine till of a proper consistence.

Asphalt Lacquer on Iron.—In order to obtain the filed places equally dark with the rest, rub the iron lightly and thinly with the best quality of soot or bone-black, then burn in and rub off with turpentine. By now coating the article with asphalt lacquer it shows a uniformly black and durable color.

To Lacquer Brass.—In preparing brass for colorless, or nearly colorless lacquer, the articles, after being annealed, pickled, scoured and washed, are either dipped for an instant into pure commercial nitric acid, washed in clear water and dried in sawdust, or immersed in a mixture of 1 part of nitric acid with 4 of water until a white curd covers the surface, at which moment the articles are withdrawn, washed in clear water and dried in sawdust. In the first case the brass will be bright; in the latter a dead flat, which is usually relieved by burnishing the prominent parts. Then the articles are dipped for an instant in commercial nitric acid, well washed in water containing tartar to preserve the color till lacquered, and dried in warm sawdust. So prepared, the articles are heated on a plate and varnished. Spirit varnish is used, which consists in its simple form of 1 oz. of shellac dissolved in 1 pint of alcohol. For imparting richness of color to this simple varnish such coloring substances as red sanders, dragon's blood and annotto are added. To lower the tone of color turmeric, gamboge, saffron, cape aloes and sandarac are used. The first group reddens, the second yellows the varnish, while a mixture of the two gives a pleasing orange, and various tints can be got by suitable mixtures.

Small circular work, after being well scoured and burnished, if necessary, is best lacquered in the lathe. The work should be slightly warmed over a clear charcoal fire, or in a stove, and the lacquer applied very thinly with a soft camel's-hair brush. A charcoal brazier should be held under the work for a few seconds after the application of the lacquer to prevent chilling. To lacquer a flat surface, clean carefully by boiling in potash and water. Dip in hydrochloric acid, if it be desirable to heighten the color of the brass; wash well, first in cold water, then in hot (removing any

black muddiness with a brush), and dry in hot sawdust. When dry, burnish if required. Place upon a flat iron plate, just lukewarm. Pass the lacquer quickly but evenly over the surface by means of a rather large but fine camel's-hair brush. Be careful not to pass twice over the same spot, or a ridge is almost sure to appear. Warm the lower plate until the work is quite dry.

Lacquer for Brass.—Seed lac, 12 ozs.; copal, 4 ozs.; dragon's blood, 80 grains; extract of red sanders wood, 50 grains; saffron, 70 grains; pulverized glass, ½ lb.; spirits of wine, 2 quarts.

Pale Lacquer for Brass.—Methylated spirits of wine, 1 gallon; shellac, 5 ozs.; sandarac, 4 ozs.; gum elemi, 1 oz. Mix in a tin flask, and expose to a gentle heat for a day or two; then strain off, and add ½ gallon of spirit to the sediment and treat as before.

Pale Gold Lacquer for Brass.—Methylated spirits of wine, 2 gallons; seed lac bruised, 20 ozs.; and red sanders, 1 oz. Dissolve and strain.

Gold Colored Lacquer for Brass Watch-cases, etc.—Seed lac, 6 ozs.; amber and gamboge, each 2 ozs.; extract of red sanders wood in water, 24 grains; dragon's blood, 60 grains; Oriental saffron, 36 grains; powdered glass, 4 ozs.; pure alcohol, 36 ozs. The seed lac, gamboge and dragon's blood are pounded very fine on porphyry, or clean marble, and mixed with the powdered glass. Over this mixture is poured the tincture formed by infusing the saffron and the sanders wood extract in the alcohol for 24 hours, then straining. Metallic articles that are to be coated with this varnish are heated, and, if they admit of it, immersed made up in packets.

Gold Lacquer for Metallic Articles.—Prepare a concentrated solution of picric acid in alcohol, and add to it alcoholic solution of pale shellac until a test shows the desired gold color. Then add for every 2 lbs. of lacquer 2½ drachms of boric acid, previously dissolved in as little spirit of wine as possible.

Gold Lacquer for Tin Plate.—Carefully cleanse the tin plate, and apply with a broad soft brush a coat of a mixture of 1 part of linseed oil and 2 parts of dark copal lacquer. Dry the coated plates in a drying stove. Tin plate thus lacquered can be bent and hammered without the lacquer cracking off or losing its lustre.

Green Lacquer.—Mix 10 ozs. of shellac, 12 ozs. of turmeric, 8 ozs. of gum sandarac, and 2 ozs. each of gum elemi and gamboge in 2 gallons of methylated spirits; expose to a gentle heat, strain, add 1 gallon of spirit to the sediment, and treat as before.

Iron Lacquer for Blacksmiths, Locksmiths and Founders.—A lacquer protecting the iron from rust and presenting a beautiful black appearance is prepared as follows: Dissolve 8 ozs. of asphalt in 4 lbs. of pine oil by heating in a copper kettle, and add 8 ozs. of colophony. Solution must be effected carefully to prevent the flame from coming in contact with and igniting the pine oil vapors. For coating iron on a large scale asphalt tar is used, the links of chains being first freed from scales by immersion in strongly diluted hydrochloric acid.

Lacquers for Gold.—Alcohol, 1 gallon; turmeric ½ lb.; macerate for a week, then filter, and add gamboge, 2 ozs.; shellac, 6 ozs.; gum sandarac, 1¾ lbs.; dissolve in a warm bath, and add 1 quart common turpentine varnish. For *red* lacquer, use 1½ lbs. of annotto instead of the turmeric, and 8 ozs. of dragon's blood instead of the gamboge.

Pale Lacquer for Gold.—Alcohol, 36 ozs.; turmeric, 12 drachms; dragon's blood, 4 drachms; red sanders, 1 drachm; hay saffron, 2 drachms; shellac, 3 ozs.; gum sandarac, 6 drachms; gum mastic, 6 drachms; Canada balsam, 6 drachms; dissolve, and add 4½ drachms of spirit of turpentine.

Lacquer for Philosophical Instruments.—Gamboge, 3 ozs.; sandarac and elemi, each 8 ozs.; best dragon's blood, 4 ozs.; *terra merita*,* 3 ozs.; oriental saffron, 8 grains; seed lac, 4 ozs.; pulverized glass, 12 ozs.; pure alcohol, 80 ozs. The dragon's blood, elemi, seed lac, and gamboge are all pounded and mixed with the glass. Over them is poured the tincture obtained by infusing the saffron and *terra merita* in the alcohol for 24 hours. This tincture,

* *Terra merita* is the root of an Indian plant; it is of a red color, and much used in dyeing. In varnishing it is only employed in the form of a tincture, and is particularly well adapted for the mixture of those coloring parts which contribute the most towards giving metals the color of gold. In choosing it be careful to observe that it is sound and compact.

before being poured over the dragon's blood, etc., should be strained through a piece of clean linen cloth, and strongly squeezed. If the dragon's blood gives too high a color, the quantity may be lessened according to circumstances. The same is the case with the other coloring matters. This lacquer has a very good effect when applied to many cast or moulded articles used in ornamenting furniture.

Lacquer for Steel.—A good lacquer for steel is prepared by dissolving 10 parts of pure mastic, 5 of camphor, 15 of sandarac, and 5 of elemi in pure alcohol, and filtering the solution. The lacquer is used cold; it dries clear and transparent.

Lacquer for Tinfoil.—Dissolve 7 ozs. of shellac in 1 quart of alcohol, and filter the solution. Allow the slime remaining upon the filter to drain off, covering the funnel with a glass plate to prevent as much as possible the evaporation of alcohol. To the shellac varnish thus obtained add 3½ ozs. of best white gum elemi and 14 drachms of Venetian turpentine, and let the whole stand in a moderately warm place, stirring frequently. Then filter, press out the residue, consisting almost entirely of gum elemi, and add it to the filtrate. The varnish thus obtained may be colored as desired.

Metallic Gold Color.—Metallic articles coated with a very fine gold varnish are frequently brought into commerce from France and England. This varnish consists, according to Hart, of a very soft, almost liquid amalgam of 1 part of zinc and 12 parts of mercury. This amalgam is diluted with hydrochloric acid, and the copper articles are boiled in the mixture; they are then washed in clean water and dried in saw-dust. The articles to be varnished must previously be carefully cleansed with dilute nitric acid.

To Lacquer Optical Instruments.—Before lacquering the brass must receive the highest possible finish and polish. This is done by taking out the marks of the file with finer and finer sorts of emery cloth or paper, then polishing with rotten-stone or oil, and giving the article, after this has been cleaned off, a final touch with a buff-stick and jewelers' rouge. The article must be carefully wiped clean, and care taken that it is not touched afterwards with

the fingers, as these would leave a greasy mark. Care must be taken at every step to invariably lay the successive strokes of the emery cloth or paper and polishers in the same direction. When the desired degree of polish has been attained, a quantity of lacquer is poured into a convenient vessel. A fine, flat camel's-hair brush is taken, and the article being gently warmed and held on the left hand, a small quantity of the lacquer is taken up on the brush, and the brush is drawn over the brass with straight strokes, always, if possible, in the same direction. The article may generally be held by screwing a piece of wire into some hole in it, and holding the wire with a small hand-vise. As many coats of the lacquer as desired may be given by keeping the brass hot. The degree of heat is an important element in the success of the operation ; it must not exceed the temperature of boiling water, and in some cases this would be too great. Considerable skill is required in lacquering well, and that skill can only be attained after a great deal of experience. The great secret of lacquering for beginners is to take as little as possible of the lacquer at a time on the brush, have the article perfectly clean, a good brush with no loose hairs in it, and not make the article too hot.

What has been described in the foregoing is the process adopted for lacquering the outside of photographic lens mounts, or all those portions of the brass work where the light does not pass. The inside of the mounts, however, is treated in an entirely different way. Where the light passes there must be a surface as nearly dead black as can be got. This is obtained in the inside of the tubes by mixing finely triturated lampblack with the lacquer used for the outside, and applying the black lacquer in one or more coats with heat to the inside of the tube. The result is a finely grained black surface which reflects no light. As soon as the surface has received one or two coats no more must be given, as the repeated application of the lacquer would make the surface glossy, the very thing which it is wished to avoid. This method of blackening the brass does excellently for all portions which are not to come in contact with the fingers ; but wherever the brass requires to be handled recourse must be had to something different from lampblack. Nitrate of

copper may be especially recommended for this purpose. A solution is prepared by dissolving copper wire in nitric acid, weakened by adding 3 or 4 parts of water to 1 of acid. The article to be blackened is heated pretty hot, and then dipped into the solution; it is then taken out and heated over a Bunsen burner or spirit lamp. When the article is heated to the proper temperature the green color of the copper first appears, and, as the heat is increased, the article becomes a fine dead-black. It is not necessary to lacquer it, it being best to give it simply a good brushing to remove the dust, when it may be considered finished. The color becomes blacker by the application of a single coat of lacquer, provided it is not put on in sufficient quantity to make the surface glisten—too much lacquer, however, invariably produces an objectionable polished surface.

Coating for Bars of Spring Steel not Acted Upon by Acids, Alkalies, etc.—The bars are first coated with copal or asphalt lacquer, and dried at a high temperature. They are then wrapped in several layers of strongly-pressed paper impregnated with chromium glue, and subjected to a very heavy pressure, and finally receive a coat of the following compound: China clay, 50 parts; shellac, 10; sandarac, 8; elemi, 3; gun cotton, 2; camphor, ½; and oil of lavender, 5, dissolved in 100 of alcohol. When half dry, the bars are again subjected to pressure, and, when entirely dry, ground.

Black Coating for Iron.—To protect iron as cheaply as possible from atmospheric influences, it is to be coated with ozokerite. Ozokerite forms a brown, resinous mass and melts at about 140° F. For lacquering iron articles the ozokerite is melted in a kettle, and the melted mass heated to about the boiling point of water. The sheets to be lacquered, which are to be previously scoured bright by rubbing with sand, are immersed in the melted mass, and after draining off, the ozokerite is ignited by holding the sheets over a coal fire. After the ozokerite has burned for some time the flame extinguishes, generally by itself, and the iron appears provided with very firmly adhering black coating which perfectly resists all atmospheric influences, and also the action of acids and alkaline bodies. If the iron is to be used for vessels for the reception of

alkaline fluids, it is recommended to repeat the lacquering in the manner described.

New Rust Preventive.—For the preparation of this preventive the crude oils obtained in the dry distillation of brown coal, peat or other bituminous substances are, according to Dr. L. Beckert, subjected to a second distillation. The distillate passing over at 482° to 572° F. forms the initial point for the process. Caoutchouc rolled out thin and cut into strips is poured over with four times its quantity of this oil and allowed to stand for 8 days, whereby it is converted into a homogeneous and soft mass which can be drawn into threads. This mass is worked by means of a stirring apparatus with pale vulcan oil or other suitable hydrocarbon until a homogeneous, clear fluid drawing threads is formed. In this manner the mechanical incorporation of the caoutchouc with the oil is effected without a separation afterwards taking place. By applying the oil in as thin a layer as possible by means of a flannel rag to a metallic surface, and drying slowly, a thin film of caoutchouc oil is formed which affords an absolute protection against atmospheric influences. After exposure for one year not the slightest cracks, it is claimed, could be detected in the film of oil even by a microscopical examination. To remove the oil the articles are thoroughly oiled with caoutchouc oil; after allowing the latter to act for 12 to 24 hours, the clean metallic surface is restored by wiping off. It is claimed that the caoutchouc oil is also especially adapted for loosening rust already present.

To Protect Iron and Steel from Rust.—The following method is but little known, although it deserves preference over many others: Add 1¾ pints of cold water to 7 ozs. of quick lime. Let the mixture stand until the supernatant fluid is entirely clear. Then pour this off and mix it with enough olive oil to form a thick cream, or rather to the consistency of melted and recongealed butter. Grease the articles of iron or steel with this compound, and then wrap them up in paper, or, if this cannot be done, apply the mixture somewhat more thickly.

To Protect Lightning-rods, Metal Roofs, etc., from Rust.—Convert 2 parts of graphite mixed with 8 parts of sulphide of lead and

2 of sulphate of zinc into an impalpable powder, and add gradually 30 parts of linseed oil varnish previously heated to the boiling point. This varnish dries very quickly, and protects the metals coated with it from oxidation.

To Protect Lead Pipes it is recommended to provide them with a coat of sulphide of lead. Dissolve ½ oz. of caustic soda in 1½ quarts of water; mix the solution with one of ½ of lead nitrate (or an equivalent of another lead salt soluble in water) in ½ pint of water, and heat the mixture to 195° F. As soon as a sufficient quantity of lead salt has been added the fluid becomes turbid, and must be quickly filtered through asbestus or a similar material. To the clear fluid add 2½ ozs. of hot water containing 1 drachm of sulphocarbonide in solution. In using the fluid it is best to heat it to 150° F., and to hold the thoroughly cleansed lead pipe in it for a few moments, when it will be quickly coated with a fine layer of sulphide of lead. If the lead has been thoroughly cleansed the sulphide of lead adheres very tenaciously and can be polished with a piece of leather.

Painting of Iron.—On exposure to the atmospheric air all metals soon lose their metallic lustre; they oxidize by absorbing oxygen from the air. Iron becomes coated with a layer of hydrated sesquioxide of iron or rust; copper with carbonate of copper as well as with the hydrate, while zinc also oxidizes very rapidly, it becoming dull gray. This change takes place most rapidly in iron, every drop of rain causing a rust stain, and, hence, only iron perfectly free from rust can be successfully painted. When the oxidizing process has once commenced, its progress may for a time be interrupted by painting, but it progresses slowly even under the paint, the latter finally peeling off together with the layer of rust. Copper oxidizes, but so slowly that protecting agents are seldom used. While, when applied to wood, the paint penetrates the pores, thus allowing of an intimate mechanical union, it cannot penetrate the fine pores of the metals and, hence, the protection it offers consists simply of a protecting coat, and consequently a paint entirely different from that used for wood is required for iron. The principal point in painting iron is the priming color.

If this is defective or incorrectly applied the efficacy of the entire work is doubtful, even if the succeeding coats are correctly applied, because in such a case a union between the priming and body colors only takes place, which, if the former does not firmly adhere to the iron, soon becomes full of cracks and scales off. For the priming color to adhere firmly to the iron three conditions are required: 1, it must be capable of drying quickly and thoroughly; 2, it must be thinly-fluid; and 3, it must be applied in a thin layer only. The priming color should dry quickly, so that by the lowering of the temperature with a content of moisture remaining in the air, which occurs quite frequently, and, as a rule, toward evening, a precipitate of atmospheric water is not formed upon the iron before the paint has become solid. A sort of emulsion of the paint takes place thereby, in consequence of which it never dries to a solid, homogeneous mass. If the iron is painted in the open air a precipitate of moisture may also be formed upon it by the radiation of heat from the iron. The power of the radiating heat of iron, as well as of metals in general, is, to be sure, small, but Mellam's experiments have shown that it increases considerably when the metallic surface is coated with varnish.

The priming color should be thinly-fluid in order to be sure that all inequalities of the surface to be painted may be covered. If a mistake is made in this direction, as frequently happens when the paint is too thick and the painter is not very careful, the coating readily tears under the expansion of the metallic surface by heat, air and moisture penetrating into the fissures and gradually undermining the entire coat of paint by the formation of rust. And, finally, the layer of paint should be very thin, because paints on iron and other non-porous surfaces dry very slowly. If a thick layer is applied, only a film is formed on top, under which the paint remains fluid for a long time.

Paint for Sheet-iron Roofs.—The priming color is linseed oil with red-lead; for painting use 1 part of verdigris, 1 of white-lead, and 3 of linseed oil; *or*, ½ of verdigris, 1½ of white-lead and 2½ of linseed oil. The sheet-iron receives three coats, the first

before it is used, the second after the first is thoroughly dry, and the third three days later.

Paint for Preserving Zinc Roofs.—Fat or resinous paints for zinc roofs must be prepared with an abundant content of copper by the actual chemical solution of suitable copper preparations in the varnishes and oils. Such paints combine very intimately with the zinc surfaces, so that they resist the most abrupt changes of temperature without scaling off. For the preparation of such paints either copper soap prepared by precipitating a solution of copper salt with soap solution is dissolved in varnish, or the emulsion, like Russian train-oil paint, mixed with solution of copper salt. Russian train-oil paint is prepared by mixing train-oil with a solution of soda or potash and suitable mineral colors, so that a thinly-fluid paint is formed.

Puscher claims to have found a simple process of applying a very durable paint of various colors to sheet-zinc. It is based upon the use of basic acetate of lead. To a solution of this salt colcothar may, for instance, be added, the result being a very agreeable, brown-red paint. Such paint was used for painting the five domes of the Nürnberg synagogue. By adding other coloring substances light, dark and gray colors as well as yellowish shades can be obtained, and thus zinc castings used for architectural purposes may be given the appearances of sculptured work.

Black Varnish for Iron and Steel.—A black varnish of a splendid tone is produced on steel and iron by turpentine and sulphur boiled together, laid on with a brush. The evaporation of the turpentine leaves a thin layer of sulphur, which unites with the iron when heated a short time over a gas or spirit flame. The varnish is durable and perfect.

Black Varnish for Zinc.—Dissolve equal parts of chlorate of potash and blue vitriol in 36 times as much warm water and allow the solution to cool. If the blue vitriol used contains iron, it is precipitated as a hydrated oxide, and can be removed by decantation or filtration. The zinc castings are then immersed for a few seconds in the solution until quite black, rinsed off in water and dried. Even before it is completely dry the black coating adheres

to the article so that it may be wiped dry with a cloth. If copper-colored spots appear during the operation the solution is applied to them a second time, and after a while they turn black, when the article is washed and dried. On rubbing the coating acquires a glittering appearance like indigo, which disappears on applying a few drops of linseed oil varnish or "wax milk," and the zinc then has a deep-black color and gloss. The "wax milk" is prepared by boiling 1 part of yellow soap and 5 of Japanese wax in 21 of water until the soap dissolves. When cold it has the consistency of a salve, and will keep in closed vessels for an indefinite time.

Bright Asphalt Varnish for Sheet Metals.—Boil coal-tar until it shows a disposition to harden on cooling; this can be ascertained by rubbing a little on a piece of metal. Then add about 20 per cent. of lump asphalt, stirring it with the boiling coal-tar until all the lumps are melted, when it is allowed to cool and kept for use.

Colored Varnish for Sheet Metal.—Rub 7½ drachms of acetate of copper to a fine powder in a mortar, spread the powder in a thin layer upon a porcelain plate, and let it stand in a moderately warm place. In a few days the water of crystallization and most of the acetic acid will be evaporated. Triturate the light-brown powder which remains behind with some oil of turpentine, and stir in 3½ ozs. of a fine quality of fat copal varnish heated to 167° F. If the acetate of copper has been rubbed extraordinarily fine, the larger portion of it will be dissolved after stirring ¼ hour. The varnish is then poured into a glass bottle, placed in a warm place, and frequently shaken. The small quantity of acetate of copper which settles on the bottom may be used in the preparation of further portions of varnish. This varnish is dark green; four to five coats are required to produce a beautiful green lustre upon articles of sheet metal; but in order to obtain a variety of gold shades two coats are sufficient if the respective articles are heated in a drying chamber or upon uniformly heated metal plates. According to the time of heating, either a greenish or yellow shade, or a dark yellow, orange or reddish brown may be obtained. These colors surpass in lustre those produced with English gold varnish, and have the advantage

of remaining constant on exposure to light. If a good quality of copal varnish is used in the preparation of a polychromatic varnish or lacquer, the sheet metal may even be hammered. The production of gold colors depends on the reduction of oxide of copper, it yielding a gold color when dissolved in small quantity by the copal varnish. The more heat is applied the greater the reduction which takes place, and hence the darker color.

Green Varnish for Metals.—Dissolve finely pulverized gum sandarac or mastic in strong potash lye until it will dissolve no more. Dilute the solution with water and precipitate it with a solution of copper salt, either sulphate or acetate. The green precipitate is washed, dried, and dissolved in oil of turpentine, producing a fine green varnish, which does not change under the effect of light, and is especially useful for ornamental iron work.

Green Transparent Varnish.—Grind a small quantity of Chinese blue with double the quantity of finely powdered chromate of potash, add a sufficient quantity of copal varnish, thinned with turpentine. The tone may be altered by more or less of one or the other ingredients.

Varnish for Iron Work.—Dissolve in about 2 lbs. of tar oil ½ lb. of asphalt and a like quantity of pounded resin, mix hot in an iron kettle, care being taken to prevent any contact with the flame. When cold the varnish is ready for use. This varnish is for outdoor wood and iron work.

Varnish for Common Work.—This varnish is intended for protecting surfaces against atmospheric influences. It has been used for coating wood and iron work with great advantage. Take 3 lbs. of resin and powder it, place it in a tin can, and add 2½ pints of spirits of turpentine, shake well, and let it stand, occasionally agitating it, for a day or two. Then add of boiled linseed oil 5 quarts, shake the whole together, and allow it to stand in a warm room till clear. The clear portion is decanted and used, or reduced with spirits of turpentine until of the proper consistency.

Varnish for Iron Patterns.—Add to oil of turpentine, drop by drop, strong commercial sulphuric acid; the acid will cause a dark syrupy precipitate in the oil of turpentine; keep adding drops of

sulphuric acid until no more precipitate is formed; then pour out the liquid and wash the syrupy mass with water, and it is ready for use. Heat the iron to be varnished to a moderate heat, apply the syrupy product, and allow it to dry.

Varnish for Metals According to Max Innes.—Potash or soda soap is decomposed by a metallic salt—best sulphate of zinc. The metallic soap thus formed is purified by washing, and, after adding 10 per cent. of tallow, the whole is diluted with petroleum or another volatile oil, which dissolves the metallic soap. It is then filtered until entirely bright and clear, and kept for use in well-closed vessels.

XIV.

SOLDERING AND SOLDERS.

Soldering is the process of uniting the edges or surfaces of similar or dissimilar metals and alloys by partial fusion. In general alloys or solders of various and greater degrees of fusibility than the metals to be joined are placed between them, and the solder when fused unites the three parts into a solid mass. Less frequently the surfaces or edges are simply melted together with an additional portion of the same metal. The solders are broadly distinguished as *hard solders* and *soft solders;* the former only fuse at a red heat, and are consequently suitable alone to metals and alloys which will endure that temperature; the soft solders melt at very low degrees of heat, and may be used for nearly all the metals.

The attachment is in every case the stronger the more nearly the metals and solders respectively agree in hardness and malleability. Thus, if two pieces of brass or copper, or one of each are brazed together, or united with spelter-solder—an alloy nearly as tough as the brass—the work may be hammered, bent, and rolled almost as freely as the same metals when not soldered, because of the nearly equal cohesive strength of the three parts. Lead, tin, or pewter are also malleable from the near agreement of these substances;

whereas, when copper, brass, and iron are soft-soldered, a blow of the hammer, or any accidental violence, is almost certain to break the joint asunder so long as the joint is weaker than the metal generally; and, therefore, the joint is only safe when the surrounding metal, from its *thinness*, is no stronger than the solder, so that the two may yield in common to any disturbing cause.

In hard-soldering it is frequently necessary to bind the works together in their respective positions; this is done with soft iron *binding wire* which for delicate jewelry work is exceedingly fine, and for stronger work is $\frac{1}{20}$ or $\frac{1}{3}$-inch in diameter. It is passed around the work in loops, the ends of which are twisted together with the pliers. In soft soldering the binding wire is scarcely ever used, as, from the moderate and local application of the heat, the hands may generally be freely used in retaining most of thin work in position during the process. Thick work is handled with pliers or tongs whilst being soft-soldered, and is often treated much like glue joints, if we conceive the wood to be replaced by metal, and the glue by solder, as the two surfaces are frequently coated or tinned whilst separated, and then rubbed together to distribute and exclude the greater part of the solder.

For the soft solders, the soldering iron is the most general agent for applying the heat; for the hard solder, forge or other fires, or the blow-pipe, are generally adopted. *Brazing* (used with sheet brass and sheet copper) may be defined as soldering with fusible brass, and hence as a form of hard soldering.

The soldering iron—more correctly the copper soldering bit—consists of a small piece of solid copper rivetted between the forked end of a split iron rod, the whole being provided with a wooden handle. All works in tinned and sheet iron, and many of those in copper and brass, are soldered with the copper-bit, which in general suffices to convey all the heat required to melt the more fusible solders now employed. If the copper-bit has not been previously tinned, it is heated in a small charcoal stove, or otherwise, to a dull red, and quickly filed to a clean metallic surface; it is then rubbed immediately, first upon a lump of sal-ammoniac, and next upon a copper or tin plate upon which a few drops of solder have

been placed. This will completely coat the tool; it is then wiped clean with a piece of tow and is ready for use.

The copper-bit or end must always, as has been said, be tinned, or covered with tin, before using. This always needs to be done. Here is another plan: File it bright with a fine file, and give it a pointed end, not too sharp, and then put it into your charcoal or coke fire. Get a soft red brick and scoop out a hole as big as a cherry in its top surface. When the bit is not quite red hot, hold the bar of solder in your left hand over the hole in the brick, and touch it with the hot bit in such a way that the metal drops into the cavity; drop also a pinch of powdered resin on it. Now rub the bit round and round in the brick until it gets cool, and by that time, if the operation has been properly performed, it will be coated with solder.

It is customary to keep two soldering irons in use, so that while one is in hand the other may be heating in the stove. It is impossible to make satisfactory work unless the tool be kept at a sufficient heat. It should not, however, be raised to too great a heat or the tinning will be burned off and will need to be replaced.

Besides the usual copper-bit the plumber employs a large heavy bulbous iron in soldering. This is especially used for joints in lead pipe, which require to be very sound. These are generally extremely clumsy in appearance, as by the aid of the hot iron and a piece of tick held in the left hand the plumber manages to plaster a great bulbous patch of solder round the point of junction, which is termed a "*wiped*" *joint.*

The blow-pipe (mouth) is used to some extent in soft soldering, principally by the gas-fitter, who is generally remarkably expert in making therewith joints in his composition pipes. These are not made like the plumber's, by inserting one end of the pipe in the other and plastering a bulb of solder around the place, but by cutting off the pipes with a fine saw and filing them up square and smooth to butt together into a mitre or T joint. These joints have frequently to be made in very awkward and confined situations amongst joists under floors, etc., and are generally effected

by applying the heat from one side only, by holding a small bundle of dried ignited rushes there and forcing the flame thus obtained upon the joints with a blow-pipe. They generally use a solder rich in tin, and employ a flux of oil and resin in equal parts.

The pewterers generally use the hot-air blast by means of a peculiar apparatus employed only in their trade. They use fusible solder containing bismuth, and for flux a common green olive oil, termed Gallipoli oil.

For hard soldering an intense fire heat is required, similar to that obtained in the smith's forge. In fact the ordinary blacksmith's forge is frequently used for brazing, although the process is injurious to the fuel as concerns its normal purpose. The brazier's hearth, for extensive work, is generally a plate of iron about 4 × 3 feet, supported on four legs at its corners, and with a central opening about 2 feet by 1 foot, and 6 inches deep for the fuel. The blast is generally supplied by a fan, and the tuyere-irons have large apertures.

Fresh coal should never be used, but charcoal, or, failing that, coke or cinders. Lard in the fire is very prejudicial.

In all cases of hard-soldering or brazing the meeting edges are to be scraped or filed clean, especially when the heat used will not reach the *red* degree. The work in copper, iron, brass, etc., having been prepared and the joints retained in position by binding with iron wire when needed, the granulated spelter and borax are mixed in a cup with a very little water, and spread along the joints by a slip of sheet-metal or a small spoon. The work is then placed above the clear fire, first at a small distance, gradually to evaporate the moisture and deprive the borax of its water of crystallization. During this process the flux boils up with a frothy appearance, and sometimes shifts the solder away. The heat is now increased, and when the metal assumes a faint red the borax melts like glass. As the metal becomes deeper red the solder also fuses, generally, if it contains any zinc, with a slight blue flame. Generally at this point the solder "flushes" or disappears in the work. Should it not do so, and appear refractory on the score of running into the joint, the work may be tapped with the tongs in order to

make it move. Care must, of course, be taken that the heat is not so much raised as to melt the work as well as the solder. If the work be iron, there is, of course, little need of precaution.

If iron is to be brazed the meeting surfaces must be filed bright. Make a little borax into a paste with water and smear them over with this. Next tie them together with fine iron wire; just enough to prevent the pieces from coming apart. Then wind them round and round at the place of the joint with several coils of fine brass wire, rubbing them over with the borax paste. This is then laid on the fire and the blast put on. Presently a small blue flame will be seen reflecting over the place. This is a sign that the brass wire is melting and the heat is dissipating the zinc constituents of the brass, and the brass having melted and run into the joint the job is done.

It is only iron, however, to which so much heat can be applied. For brass and copper a more fusible metal than brass must be employed. This solder is called "*spelter*," and is composed of equal parts of copper and zinc. In fact it is a very soft kind of brass, and liquefies at a much lower temperature than copper or ordinary brass.

The blow-pipe is largely used in hard soldering and brazing, especially for work in the precious metals. The ordinary blow-pipe is a light conical brass tube about 10 or 12 inches long, from ½-inch to ¼-inch in diameter at the end for the mouth, and from $\frac{1}{16}$ to $\frac{1}{50}$-inch at the aperture or jet. The small end is bent in a quadrant, that the flame may be immediately in sight. Very usually it is fitted with a small hollow brass ball just below the quadrant, to serve as a receptacle for the condensed vapor from the lungs. This instrument is generally used with a lamp of a wick from ¼ to 1 inch in diameter and produces a flame of great heat, the object exposed to it being generally placed upon charcoal. Gas is frequently used in conjunction with the blow-pipe, and this is especially useful for sheet-brass, the work being held in place by wire ties if necessary, and either laid upon a flat piece of pumice-stone or held in a pair of pliers.

Since soldering must be executed with the assistance of heat,

and the places to be joined would soon become again coated with oxide, even if previously cleansed, care must be had to either exclude the atmospheric air from the metal during the operation, or to dissolve the oxides formed, or to reduce them to metal. Besides various soldering liquids, the following substances are used as fluxes: clay, borax, powdered glass, phosphoric acid and phosphates, cryolite, hydrochloric acid, chloride of zinc, colophony, sal-ammoniac and soldering grease. *Clay* is only used for the exclusion of the air, especially in soldering iron. *Powdered glass* excludes the air only after fusion, consequently when oxides have already formed, which, however, dissolve readily in the fused glass, entering into combination with the free silicic acid of the glass.

Hydrochloric Acid exerts a corroding and dissolving effect upon the oxides. It is much used in soldering zinc, it not being necessary to previously brighten the metal. Still better is a solution of *chloride of zinc*, which may be used for all kinds of metal. When the places to be joined are free from dirt they need not be filed or scraped; iron alone has to be cleansed, which is readily effected by brushing the places to be soldered with hydrochloric acid and rubbing with a piece of sheet-zinc.

Powdered Colophony, turpentine and even oil of turpentine are used as soldering agents. At the heat required for soldering they melt and decompose, hydrogen and carbon being formed. It is generally supposed that it is the carbon alone which effects the reduction of the metallic oxide formed on the joint to be soldered; however, according to Spencer's experiments, the hydrogen liberated in the distillation of resins also plays an important part as a reducing agent, and, therefore, beeswax especially would be still more suitable as a soldering agent.

The flux mostly used in soft soldering is a

Soldering Liquid prepared as follows: Dissolve small pieces of zinc in pure hydrochloric acid until effervescence ceases. After a few days take out the undissolved zinc, filter the solution, compound it with ⅓ its volume of spirits of sal-ammoniac, and finally dilute with rain water. This soldering liquid causes no rust on iron

or steel, and does excellent service in all soldering, as well as tinning operations.

Soldering Paste.—By mixing solution of chloride of tin with starch paste a syrupy liquid is obtained which is frequently used in soldering, it being more readily applied to the soldering seam than ordinary soldering liquid.

Soldering Fat.—Besides chloride of tin, soldering fat is also used in soldering tin-plate, etc. It is prepared as follows: Melt in a pot over a gentle coal-fire 1 lb. of olive oil and 1 lb. of tallow, and after stirring in 8 ozs. of pulverized colophony, allow the mass to boil up. When the mixture is sufficiently cool add, with constant stirring, ¼ pint of water previously saturated with pulverized sal-ammoniac, whereby the mass acquires a yellow color, and is ready for use.

The above-mentioned fluxes cannot be used for hard soldering, as they would burn or volatilize at the temperature required. Instead of them borax or phosphates and occasionally phosphoric acid are employed, these substances possessing in a high degree the power of dissolving metallic oxides, and at a high temperature fusing with them together to a glass-like mass. They are used either in a solid form or as solution. Ordinary borax can only be used for preparing soldering liquid, since, when used dry, it loses by heating its water of crystallization, swells up and causes disturbance in the operation. For use in a powdered state borax has to be calcined; this is readily effected by heating ordinary borax until it forms a readily friable mass.

Phosphoric acid is used diluted either with water or spirits of wine.

Müller's Soldering Liquid consists of a solution of phosphoric acid in alcohol. It is prepared by dissolving phosphorus in nitric acid, evaporating the solution to expel any excess of nitric acid and mixing the syrupy mass with an equal quantity of strong alcohol. The phosphoric acid dissolves the layer of oxide, the combination formed melting under the soldering iron, and is displaced by the melted solder which now comes in contact with the bright metallic

surface. This fluid can be advantageously used in soldering copper, as well as brass, bronze and argetan.

Gauduin's Soldering Liquid for copper and bronze consists of a mixture of finely pulverized cryolite and a solution of phosphoric acid in spirits of wine.

New Soldering Liquid.—Dissolve 1 part each of lactic acid and glycerin in 8 of water. This liquid is claimed to possess the advantage over zinc chloride of not being corrosive, or injurious to the health of the workman.

Soft Solders.—The soft solder most frequently used consists of 2 parts of tin and 1 of lead. A cheaper solder is formed by increasing the proportion of lead; 1½ tin to 1 lead is the most fusible solder unless bismuth be added. The following table gives the composition of some of these solders with their respective melting points:

Number.	Parts.		Melts at degrees F.	Number.	Parts.		Melts at degrees F.
	Tin.	Lead.			Tin.	Lead.	
1.....	1	25	558°	7.....	1½	1	334°
2.....	1	10	541	8.....	2	1	340
3.....	1	5	511	9.....	3	1	356
4.....	1	3	482	10.....	4	1	365
5.....	1	2	441	11.....	5	1	378
6.....	1	1	370	12.....	6	1	380

For ordinary plumbers' work the solders from 4 to 8 are used with tallow as a flux. For lead and tin pipes No. 8 is used with a mixture of resin and sweet oil as a flux. For Britannia metal No. 8 is used with chloride of zinc or resin as a flux. It can also be employed for soldering cast-iron and steel, with common resin or sal-ammoniac as a flux. The same solder may also be used for copper and many of its alloys, such as brass, gun metal, etc., sal-ammoniac, chloride of zinc or resin serving as a flux. Solder No. 5 is what is called in England *plumbers' sealed solder*, which is assayed and stamped by an officer of the "Plumbers' Company."

To prepare soft solder first melt the tin, best in a porcelain or stone vessel, as with the use of an iron vessel there is danger of the absorption of iron by the solder. The tin being completely melted add the lead in small portions and combine the two metals by stirring with a stick of wood. Then pour the finished alloys into suitable moulds, the best shaped being that of thin bars about 7¾ by 1½ inches and ⅛ to ¼ inch thick.

The quality of a solder is judged by the appearance of the surface of the cast pieces, special value being attached to its being radiated crystalline, which is technically called the "flower," and should have a stronger lustre than the dull ground of a dead silver color. If the solder shows a uniform gray-white color it contains too little tin, and it is best to remelt it with the addition of a small quantity of that metal.

Bismuth Solder.—Bismuth 1 part, tin 1, and lead 1. It melts at 284° F. This solder liquefies very readily and is considerably harder than ordinary soft solder, but much more expensive. Since every readily fusible metallic composition can be used for soldering the fusible alloys of cadmium and bismuth (see p. 82) might be classed with soft solders. On account of their costliness they are, however, only used in exceptional cases.

Hard Solders.—Under this name very different alloys are used, their composition depending principally on that of the metals or alloys to be soldered. Though hard solders are found in commerce every workman should learn to make his own hard solder, since in many instances he can expect success, not only by a thorough knowledge of the properties of the materials to be united, but also of the metal he proposes to flow on them.

Spelter Solder.—This is used in *brazing.* It is composed of equal parts of copper and zinc. Heat the brass in a crucible to a red-heat with a flux of charcoal dust and borax, and then add the zinc. If the zinc be put in at first it will evaporate or "burn out" before the copper melts. If heated too hot after melting the zinc will evaporate, passing into the air and coating surrounding objects with white feathery flakes. If kept melted long a little more zinc should be added if the solder is to be used on brass, but for iron consider-

able zinc may burn out before it deteriorates. It is cast in ingots, heated to a red-heat and hammered while hot. If too hot it will cake, but if at just the right temperature, it will granulate into fine, lustrous particles, not losing their metallic yellow color.

The following table shows the centesimal composition of various kinds of *hard solders* which have stood a practical test for various purposes:

	Copper.	Zinc.	Tin.	Lead.
Very refractory	57.94	42.06	.....	.....
" "	58.33	41.67	.....	.....
Refractory	50.00	50.00	.....	.....
Readily fusible	33.34	66.66	.....	.....
Half-white, readily fusible	44.00	49.90	3.30	1.20
White	57.44	27.98	14.58	.....
Malleable solder	72.00	18.00	4.00	.....
Hard solder according to Volk	53.30	46.70	.....	.....

These solders being generally prepared by melting together brass and zinc, the proportions required for the purpose are given in the following table:

	Parts.		
	Brass.	Zinc.	Tin.
Very refractory	85.42	12.58	.....
" "	7.00	1.00	.....
Refractory	3.00	1.00	.....
"	4.00	1.00	.....
Readily fusible	5.00	2.00	.....
" "	5.00	4.00	.....
Half-white	12.00	5.00	1.00
"	44.00	20.00	2.00
White	40.00	2.00	8.00
"	22.00	2.00	4.00
"	18.00	12.00	30.00
Very ductile	78.25	17.25	.....
For girdlers	81.12	18.88	.....

Solders for Aluminium.—French manufacturers use five kinds of solder in soldering aluminium; their composition is as follows:

	Parts by weight.				
	I.	II.	III.	IV.	V.
Zinc	80	85	88	90	94
Copper	8	6	5	4	2
Aluminium	12	9	7	6	4

The solders are made by first preparing an aluminium copper alloy and mixing this with the required quantity of zinc. The copper is first melted and the aluminium, divided into three or four portions, is gradually introduced into the melted copper, a perfect mixture being effected by stirring. When the last portion of aluminium has been added throw in the zinc, and at the same time some fat or resin, then stir quickly and briskly, immediately remove the crucible from the fire and pour the alloy into iron moulds previously rubbed with coal tar oil or benzine.

For soldering aluminium *with the blow-pipe* the following composition is recommended: Silver, 10 parts; copper, 10; aluminium, 20; tin, 60; zinc, 30.

For soldering with the common *soldering* iron use: Tin, 95 parts, and bismuth, 5; or tin, 97 parts, and bismuth, 3. The flux to be used in all cases is either paraffine, stearin or vaseline. The articles must be well cleaned before soldering and heated just enough to make the solder adhere.

Soldering of Aluminium Bronze.—To solder aluminium bronze with ordinary soft (pewter) solder: Cleanse well the parts to be joined from dirt and grease. Then place the parts to be soldered in a strong solution of sulphate of copper and place in the bath a rod of soft iron touching the parts to be joined. After a while a copper-like surface will be seen on the metal. Remove from bath, rinse quite clean and brighten the surfaces. These surfaces can

then be tinned by using a fluid consisting of zinc dissolved in hydrochloric acid in the ordinary way with common soft solder.

Hulot's Solder for Aluminium Bronze.—Lead-tin solder (equal parts of lead and tin) with 12.5, 25, or 50 per cent. of zinc amalgam.

Solders for Aluminium Bronze Jewelry. I. *Hard Solder for* 10 *per cent. Bronze.*—Gold, 88.88 per cent.; silver, 4.68; copper, 6.44.

II. *Middling Hard Solder for* 10 *per cent. Bronze.*—Gold, 50.40 per cent.; silver, 27.60; copper, 18.

Soft Solder for Aluminium Bronze.—Brass (copper, 70 per cent.; tin, 30), 14.30 per cent.; gold, 14.30; silver, 57.10; copper, 14.30.

Argentan Solders.—These solders being not only used for soldering German silver, but also for steel articles, efforts have been made to prepare compositions answering all demands, of which the following have stood a practical test:

I. *Readily Fusible Argentan Solder.*—Copper, 35 parts; zinc, 57; nickel, 8.

II. *Less Fusible Argentan Solder* (especially adapted for iron and steel). Copper, 38 parts; zinc, 50; nickel, 12.

Soldering Cast-iron.—In a foundry doing agricultural work there are a great many alterations to be made to patterns, and often it is desirable to solder brass to cast-iron where drilling and rivetting to the pattern would make anything but a neat job. By a great many men who work on iron patterns it is considered quite a secret to solder on cast-iron, but it is not so. The process is very much the same as in soldering on a tinned surface. If the part of iron to be soldered is cast-iron that is hard and thin, it should be polished on an emery wheel and made clean and bright. Then dip it in potash water, after which dip it for an instant in clean water and wash it quickly with undiluted hydrochloric acid of the ordinary strength; go over it with powdered resin and solder made from half tin and half lead. This must be done quickly before the surface has time to dry.

Another Plan is this: File the surface clean and wash as before,

wipe it over with a flux made of sheet zinc dissolved in hydrocnloric acid until it is surcharged, or is a saturated solution and has been diluted with its own quantity of water; then sprinkle powdered sal-ammoniac on it and heat it on a charcoal fire until the sal-ammoniac smokes. Dip it in melted tin, and then remove and rap off the surplus tin.

To Solder Cast-iron Objects.—Broken decorated cast-iron objects may be soldered by first removing the dirt from the surfaces to be joined and then brushing the latter with a scratch-brush until they are, so to say, covered with a dry coat of brass. The surfaces thus covered with brass are then tinned in the same manner as brass, and the parts soldered together in the usual way.

Soldering with Dry Lead Chloride.—The process consists in bringing the soldering plane of the heated soldering-iron in contact with the dry lead chloride. When the lead chloride is melted the solder is taken up in the usual manner and applied to the joints to be united. In this manner lead, zinc, copper, brass or iron can be readily soldered with lead with or without the use of soldering liquid. This interposing role of lead chloride for soldering purposes is also valuable for metallic coatings in a dry way by melting one metal upon the other. The articles to be coated are brought successively or simultaneously in contact with the melted lead chloride and the metal which is to furnish the coating. According to the shape of the article to be coated the melting may be effected either upon the article itself or the coating accomplished by dipping the object into the melted substances. Copper, brass and iron can in this manner be coated with zinc, tin or lead.

Gold Solders.—In color and fusibility the solders used for articles of gold should approach as nearly as possible the alloy of which the latter are made; the smaller the content of gold in the alloy to be soldered the more fusible the solder must be. The following table gives the composition of some gold solders in general use:

	Parts.			
	Gold.	Silver.	Copper.	Zinc.
Hard solder for fineness 750.....	9.0	2.0	1.0	
Soft " " 750.....	12.0	7.0	3.0	
Solder " 583.....	3.0	2.0	1.0	
" " 583.....	2.0	0.5	0.5	
" for less fineness than 583.... ...	1.0	2.0	1.0	
" " " " 583.....	1.0	2.0		
" " " " 583.....	1.0	.....	2.0	
" readily fusible.....	11.94	54.74	28.17	5.01
" " " for yellow gold.....	10.0	5.0	.....	1.0

Solder for Enamelled Work.—Articles which after being finished are to be decorated with enamel cannot be soldered with every kind of gold solder, since many enamels require so high a degree of heat for fusion as to endanger the durability of the soldered joints. Hence, solders with a high melting point have to be used. The following compositions will be found to answer all requirements:

I. *Refractory Solder.*—Gold, 74 parts; silver, 18.

II. *More Readily Fusible Solder.*—Gold (750 fineness), 32 parts; silver, 9; copper, 3.

To Remove Tarnish from Gold After Hard Soldering.—First protect the gold by painting it over with yellow ochre ground up with water and a very little borax. After soldering throw it into a pickle composed of water 6 parts and sulphuric acid 1 part. A copper boiling dish may be used for this pickle. If the article on coming out of this pickle is whitish looking and shows too much of the silver alloy, dip it for a moment in a hot mixture of sulphuric acid and saltpetre (no water). Wash and polish with rotten stone and oil; then wash again and polish with rouge.

Silver Solders.—The composition of these solders varies according to the purpose for which they are to be used. In the following, the compounds employed in the preparation of the solders most frequently used, are given.

Hard Silver Solders are used for soldering silver ware and fine articles of brass, copper, steel and iron. I. *Hard Silver Solder for the First Soldering* is generally composed of:

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.
	Parts.										
Fine silver..	4	2	19	57	66.7	66.3	50	11	16	6	9
Copper.....	....	....	1	28.6	23.3	25.7	33.4				
Brass.....	3	1	10	....	....	....	....	4	15	76	157
Zinc.....	....	....	5	14.3	10	11	16.6	1	1	18	35

II. *Softer Hard Silver Solder for After Soldering, i. e.*, for soldering articles having parts already soldered and requiring therefore a more fusible solder:

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
	Parts.								
Medium fine silver....	7	16	16	3.5	2	10.5	68.8	67.1	48.3
Zinc.....	1	1	1	1	1	3	8.2	10.5	16.1
Copper.....	....	....	....	2.6	3	4.5	2.3	24.4	32.3
Tin.....	....	....	....	....	....	....	....	....	3.3

Alloy for Cold Soldering.—An alloy which is useful when metals are required to be soldered together at a low temperature is prepared as follows: Finely divided copper is obtained by adding zinc to a solution of sulphate of copper. From 20 to 30 parts of this copper, according to the hardness required, are mixed in a cast-iron or porcelain mortar with concentrated sulphuric acid, to which are finally added 70 parts of mercury. The amalgam thus formed is thoroughly washed with water in order to remove the sulphuric acid, and after being left untouched for some time it

becomes sufficiently hard to scratch lead. In using the alloy for soldering it is warmed until it assumes the consistency of wax, in which state it can be applied to the joint.

Copper is the best material for joining iron to iron, whether wrought or cast. It unites the two surfaces very firmly, and, by reason of its ductility and toughness, allows of the soldered articles being bent into almost any shape. To solder iron or steel place a thin strip of copper along the junction, bind the plates together with wire and cover them an inch deep with clay free from sand. For soldering iron to iron bring the plates, when dry, to a white heat and then plunge them into cold water; for iron to steel or steel to steel, cool slowly from the white heat. The vitrified clay is then broken off.

To Solder Copper Wire.—In soldering copper wire for electrical work, acid is often used, and the resulting "greenness" is a sure indication of corrosion, which may extend under the solder, covering the copper and forming serious resistance against the passage of the current. Indeed, it is presumable that the resistance of both light and power as well as of signal circuits are often increased by such corrosion from the use of acid in soldering. Sal-ammoniac seems to be the natural flux with copper, but corrosion frequently takes place where this salt is used as a flux. The only flux permissible in electric soldering in copper and brass is resin. Clean copper will flux completely with resin provided the surfaces are clean when the resin is applied. A bottle of strong soda water, fitted with a sponge cover, can be carried with any soldering kit. The soda quickly removes any grease or dirt, is "killed" by contact with resin, and forms a perfect cleaning agent for preparing copper or brass for soldering with resin as a flux.

To Solder Saws.—A piece of charcoal, a blow-pipe, some spelter and borax are required. File the ends of the saw smooth, so that one side laps over the other, fit the teeth opposite each other and bind it with iron wire to keep in place. Then moisten the lap with borax dissolved in water and place the saw on the charcoal. Place the broken parts near a gas jet, sprinkle the parts previously wetted with the spelter and blow the flame of gas until the spelter

runs; let it get cool before removal. When quite cold file it flat with the other part of the saw.

To Solder Without a Soldering Iron.—Pieces of brass can be soldered without it being possible to detect the joint by filing the pieces so as to fit exactly, moistening them with a soldering liquid, then placing a piece of smooth tin-foil between them, tying them together with wire and heating over a lamp or fire until the tin-foil melts. With good soft solder almost all soldering can be done over a lamp without the use of a soldering iron. The different degrees of fusibility of solders can also be advantageously used for several solderings and joints on the same piece. By soldering first with a fine solder composed of lead, 2 parts; tin, 1; and bismuth, 2, there will be no danger of melting when close to the jointed part; another piece is soldered on with solder composed of lead, 4 parts; tin, 4; and bismuth, 1. The best soldering liquid to be used is composed of equal parts of water and hydrochloric acid saturated with zinc.

To Color Soft Solder.—For giving the solder used in soldering copper the same color as the latter, prepare first a saturated solution of pure sulphate of copper and apply it to the solder. By then touching the solder with an iron or steel wire it becomes covered with a film of copper which may be augmented as much as desired by repeated moistening with the solution of copper and touching with the wire. If the soldering is to show a yellow color mix 1 part of saturated solution of sulphate of zinc with 2 parts of solution of sulphate of copper, apply the mixture to the coppered place and rub the latter with a zinc rod. If the soldered place is to be gilded, copper it as above described, then coat with solution of gum or isinglass and scatter bronze powder upon it. This forms a surface which, when the gum is dry, can be polished.

To Make Platinum Adhere to Gold.—Platinum can be made to adhere to gold by soldering in the following manner: A small quantity of fine, or 18-carat, gold should be sweated into the surface of the platinum at nearly a white heat, so that the gold will soak into the face of the platinum. Ordinary solder will then adhere firmly to the face obtained in this manner.

Autogenous Soldering takes place by the fusion of the two edges of metals themselves without interposing another metallic alloy as a bond of union. This is accomplished by directing a jet of burning hydro-gas from a small movable beak upon the two surfaces or edges to be soldered together. Metals thus joined together are much less apt to crack asunder at the line of union by difference of temperature, flexibility, etc., than when the common soldering process is employed. This method of soldering is especially of great advantage in chemical works for joining the edges of sheet-lead for sulphuric acid chambers and concentration pans, because any solder containing tin would soon corrode.

XV.

WELDING AND WELDING COMPOUNDS.

In order to find a true analogy to welding we need go no further than the ordinary "sticking together" of two pieces of cobblers' wax, pitch, putty or clay. These are in a viscous or semi-fluid condition, and they cohere by an action similar to the transfusion or intermingling and uniting of two liquids. Iron and platinum pass through a viscous or pasty stage on their way from the solid to the liquid state, and the temperature at which this pasty condition occurs is the welding heat. The chief practical difficulty in welding iron arises from the fact that at a welding heat it is liable to oxidation, and the oxide of iron is not viscous like the metallic iron. The union of different pieces of iron and steel by welding succeeds well only when the surfaces of contact are as large as possible, free from oxide and scale, and sufficiently heated. To enlarge the surfaces of contact of two bars to be welded together the ends are upset and sloped, or the end of one bar is ripped open and the end of the other bar pointed like a wedge and inserted in the slit. Iron has to be heated to a white heat, whilst cast-steel welds at a bright red heat; by heating the latter too much it loses in quality—it *burns*.

To obtain a clean surface on the pieces to be united care must be had to remove the scale formed in heating. This is effected by scattering upon them so-called "welding powders," with which the scale forms a readily fusible slag; silicic acid (sand) and boric acid are most frequently used. In welding steel other substances are added to augment the fluidity of the slag.

Cast-iron or steel containing more than 2 per cent. of carbon cannot be welded, because the compound of iron with so much carbon is more fusible than pure iron, or than steel with less carbon, and it runs more suddenly or directly from the solid state into that of a liquid, and hence presents no workable range of weldable viscosity.

There is one point in welding steel which cannot be too strongly insisted upon, and that is that the pieces, after having been brought to the welding point, should not be struck heavily with the hammer, but only tapped lightly at first until they have begun to weld; after that the sledge or steam-hammer may be used with perfect freedom. Another important thing in welding steel is the heat. While it is impossible to give any specific rules on this point, the general rule, which will be found to hold good in all cases, is not to heat the steel any higher than is absolutely necessary to effect a weld—the higher the steel is in carbon the lower the heat at which it ought to be worked, hence necessitating heavier hammers—and next, not to finish the operation at too low a temperature. It will be best to work the steel as rapidily as possible, reheat as often as required to prevent working or finishing cold, and anneal immediately after welding the whole piece—not only the immediate vicinity of the weld—containing the weld. The annealing heat should always be higher than that at which the piece was finished. Another source of danger to the homogeneity of the finished product is to be found in cold-straightening. The presses in many mills are so constructed as to exert absolute shearing stresses, and are apt to do more harm than any subsequent service can do. Cold-straightening ought to be done at black heat, and the local effects of the press be modified by distribution over a large area. This can be accomplished by the use of broad oak wedges or the insertion of

pieces of plank. Generally, plates, angles, beams, etc., have of necessity to undergo more or less hammering in the course of construction, and as this produces effects comparable to punching and shearing, though in a much less degree, it becomes necessary, in steel construction, to modify these effects in the same way, by protecting the metal surface with wood and substituting heavy wooden mallets for sledges. In fine, the working of steel in every stage requires care—and, above all, intelligence—and the men engaged in it must be impressed with the necessity for careful manipulation and rational treatment. Undoubtedly the steel must in the first place possess the proper qualities for structural purposes, but then it must also be, subsequently, properly treated if it is to bring those qualities into the finished structure.

To Weld Cast-steel.—I. The following precautions are necessary to ensure success: Keep the cast-steel from the air while being heated; heat as quickly as possible; don't make it too hot or it will burn, and break in pieces when hammered—for cast-steel requires a low welding heat; strike lightly at first, and increase to heavy blows; don't use coals, because they contain sulphur, and will give the surface of the steel a coating of sulphide of iron; but use coke, or what the smiths term "breeze," that is, coal well burnt and the cinders washed. Use the following flux: Borax, ¼ lb.; washing potash, ¼ lb.; and a small quantity of white glass powdered; melt together, and when cold pound it. This flux will dissolve the oxide that forms. Apply some before putting into the fire to protect the surface of the work from oxide, and apply more at your own discretion. If wanted to weld cast-steel to iron, the iron will require a greater heat than steel.

II. Mix boric acid, 41.5 parts; common salt, 35; ferrocyanide of potash, 15.5 to 26.7; resin, 7.6; carbonate of soda, 3 to 5.

This mixture does excellent service. It has, however, the disadvantage of not remaining unaltered if kept for any length of time, as it gradually decomposes and assumes a blue color. But this is a minor evil, as the compound is so easily prepared.

III. Fiala of Prague uses pulverized white marble for welding cast-steel. The two pieces to be welded together are heated, and,

after rolling in marble-dust, are promptly joined together and subjected to a good hammering.

American Welding Compound for Welding Steel to Steel.—Flowers of sulphur, 1 part; sal-ammoniac, 2; borax, 10.

Another Formula is as follows: Boric acid, 41.5; common salt, 35; prussiate of potash, 15.5; calcined soda, 8.

Welding Compound to Weld Steel to Wrought-iron at a Red-heat.—I. Pulverize and mix with water 6 parts by weight of borax, 2 of sal-ammoniac, 1 of prussiate of potash, and ½ of resin. Boil the mixture, stirring it constantly, until it forms a stiff paste, which is allowed to harden over the fire. When cold pulverize and mix it with 1 part of wrought-iron filings free from rust. In using it scatter the powder upon the red-hot pieces and liquefy it over the fire.

II. Boric acid, 35 parts; common salt, 30.1; prussiate of potash, 26.7; colophony, 7.6.

To Weld Steel to Iron or Steel.—Mr. Paul Herzog gives the following as a special composition discovered by him for use in welding steel to steel or to iron: Borax, 500 parts by weight; sal-ammoniac, 70; prussiate of potash, 70; unrusted iron filings, 35. This compound is to be pulverized in a mortar, and then turned into a sheet-iron pot or crucible; water is added until a thick paste results, and then the crucible is put over a wood-fire and the contents constantly stirred. The resulting mass resembles pumice stone with green and gray streaks; this is cooled, pulverized, and is at once ready for use.

Welding Compound for Welding Wrought-iron to Wrought-iron at a Red-heat.—Borax, 1 part by weight; sal-ammoniac, ½; and water, ½. Boil these ingredients, with constant stirring, until the mixture is stiff, and then allow it to harden over the fire. When cool the compound is pulverized and intimately mixed with ⅓ part of wrought-iron filings free from rust. The pieces to be welded are first dove-tailed or tied together, and the place to be welded is made red-hot; the powder is then scattered upon it and liquefied over the fire. A few light taps with the hammer suffice to join the two pieces together.

To Thoroughly and Firmly Unite, by Welding, Steel with Steel, Cast-steel with Cast-steel and Cast-steel with Iron.—To weld steel of larger and smaller dimensions, for instance, piston-rods or spindles of spinning frames, cut off the bad end, upset it and cut it open with a chisel; then in the same manner prepare the piece to be welded on and join both parts. The part of the spindle to be welded is then heated to a slight white-heat in a charcoal fire, and some powder of the mixture given below scattered upon it by means of an iron spoon. When the powder is melted another portion is added and the welding joint closed by light blows with the hammer.

To prepare the powder, pulverize in a covered mortar, 500 parts by weight of borax, 70 of sal-ammoniac, 70 of yellow prussiate of potash and 35 of iron filings free from rust, and bring all into a sheet-iron crucible. Then add sufficient water to form a thick paste, and boil, with constant stirring, over a moderate wood-fire. When correctly manipulated a green and gray mass resembling pumice stone is formed, which, when cold, is pulverized and then ready for use. By the use of this powder many spindles and piston-rods up to a diameter of 2½ inches have been successfully welded. The powder may also be used for welding pieces of cast-steel as well as for joining cast-steel and iron.

Improved Method of Welding.—It is well known that in order to weld iron in a durable manner its surface must be free from oxide, which formerly could only be effected with a welding heat of 2,800° F. Such a high temperature is, however, injurious to the quality of the iron, and still more so to that of steel, so that many varieties of the latter could not be welded in this manner.

To overcome this difficulty pulverized borax is used, which, however, cannot be uniformly distributed over the surface of the iron. Lafitte now uses a gauze of very flexible wire, and applies the fluxing agent uniformly to both sides of the gauze, or also to paper. For small surfaces it frequently suffices to form a leaf from the agglomerated fluxing agent and filings. Instead of covering the two surfaces with powder, the wire gauze, which consists of the

same material as the substances to be welded, is placed between them and welded in. The welding takes place at a much lower temperature and the fluxing agent generally volatilizes while the wire gauze melts and unites with the surface.

To Weld Copper.—A mixture composed of 1 part soda phosphate and 2 boric acid is used. The powder is applied when the metal is at a dull red heat; it is then brought to a cherry-red and at once hammered. The greatest care must be taken that no charcoal or other solid carbon comes in contact with the points to be welded, as otherwise copper phosphide would be formed, which would cover the surface of the copper and effectually prevent a weld. In this case it is only by careful treatment in an oxidizing fire and plentiful application of the welding powder that the copper can again be welded. It is, therefore, advisable to heat the copper in a flame, for instance a gas flame. As copper is a much softer metal than iron, it is much softer at the required heat than the latter at its welding heat, and the parts welded cannot offer any great resistance to the blows of the hammer. They must, therefore, be so shaped as to be enabled to resist such blows, as well as may be, and it is also well to use a wooden hammer, which, on account of its lightness, does not exert so great a force.

Another Process is as follows: The two pieces of copper to be united having been previously shaped so that the surfaces form a lap or other suitable joint, borax is applied on and between the surfaces of the joint, which are then heated and hammered. The borax is prepared by being heated until all the water of crystallization has evaporated, when the residue is pulverized for use. After being hammered while hot, the joint is further heated to a white heat and sprinkled over with common salt or other equivalent compound suitable for the exclusion of oxygen, and then welded; or during the welding operation a current of chlorine gas may be directed upon the heated copper joint.

To Make Old Steel Rails New.—Mr. W. B. Middleton, of Lancaster, Pa., has discovered a method of welding steel which promises to confer very great benefit upon those engaged in steel working. According to the specification of the invention, which has

been patented in the United States and leading foreign countries, pieces of steel may, at a proper welding heat, be perfectly, cheaply and easily welded together after the pieces to be welded have been coated with a solution of silicate of soda or other solution in which silica is contained. In the practice of the invention the most satisfactory results have been obtained by applying a solution of silicate of soda to the pieces of steel to be welded, by dipping the pieces in the solution, or by pouring it upon them, bunching together the pieces to be welded and heating them to an ordinary welding heat and then passing them through rolls. This is the process followed with large pieces, but smaller articles can be welded under the hammer when previously treated with the solution. The inventor finds that the process is applicable for reworking old steel rails and other heavy pieces, and it renders certain kinds of steel scrap, which were formerly almost worthless, highly valuable.

Welding of Platinum.—Platinum does not oxidize when in a red hot state and may be welded without the use of welding powder by simply placing the red-hot pieces upon each other and uniting them by blows of the hammer. Nevertheless the welding together of two pieces of platinum is a difficult operation, since platinum possesses the property of yielding up the absorbed heat with great rapidity and cooling off to such an extent that the two pieces are no longer soft enough to be united. This cooling off takes place with such rapidity that the joining of the hot pieces must be hastened as much as possible, it being advisable to allow the flame of the hydrogen-gas blow-pipe to act upon the pieces of platinum during the entire operation of welding.

Electric Welding.—This process, the invention of Prof. Elihu Thomson, is a new art; for, unlike the smith, who is confined to iron, steel and platinum, it can weld any two pieces of the same metal or alloy, ranging from the most refractory metals to the alloy which fuses at 162° F. It will join dissimilar metals when the welding point of one is not too far in excess of the fusion point of the other.

The Apparatus.—The electricity is generated by one of two

methods. In the direct system the dynamo is contained in the machine below the clamps, and the armature has two windings; the one being a fine winding, which is in series with the field-magnet coils, and the other winding being merely a bar of copper in the form of a letter U, or less than a single coil. This bar being of a very low resistance, the maximum current is sufficient for welding purposes, and the terminals are connected directly with the copper clamps. Alternating currents are generated in this machine, and used for welding, in order to avoid commutators, which are necessary in direct-current machines. It should be remembered that in all dynamos the electricity is generated in alternate currents, and that these currents are in proper turn fed to brushes of opposite polarity, and thus rendered continuous. In an alternate-current dynamo the electricity is conducted from the armature to rings instead of to a commutator, and it is thus better suited for large currents, and some forms of the apparatus do not require rings, or any moving contacts. There is no electrical reason why an alternating current should be used except the convenience of its manipulation. In fact, the continuous current applied by secondary batteries has been used for this purpose.

Another form of apparatus, termed the indirect system, is more conveniently suited for large work, or in places where a number of welding machines are operated by the current from a single dynamo. The welding current is produced by conversion of the comparatively high-tension current by means of an inverted induction coil, termed a transformer. The primary circuit from the dynamo is conducted through many turns of fine wire around a soft iron ring, and upon this same ring is a single turn of a large copper bar, in which the welding current is produced by inductive effect. These currents receive 4,000 to 15,000 alternations per minute. The welding currents are not changed suddenly or by switches, as such manipulation would not be desirable or even practicable with the great currents used; but in the direct welding machine a set of resistance coils is placed in the fine circuit which passes around the field magnets, and by interposing more or less of the resistance coils in this circuit the strength of the magnets

is diminished or increased, and the welding current altered accordingly.

With the indirect machine the amount of the secondary or welding current is controlled by varying the current in the primary coil by means of a kicking coil, or by a variable shunt in the field coil, and in other ways.

In either case the apparatus is simple, and in full and complete control at will of the operator by movement of a lever, and this action controls the heat.

The Process.—In the electric welding process the two pieces to be joined are secured in firm end contact by a pair of adjustable copper clamps, which are placed upon the top of the apparatus. An electric current of large volume is passed through the pieces, and the contact between them being of less conductivity than the homogeneous metal, heating ensues at this place, as the juncture is brought to the proper temperature by the gradual motion of the regulating lever, and as the metal softens the clamps are pressed towards each other to insure a continuous metallic union across the bar.

The weld begins at the centre and proceeds radially towards the surface, as the temperature becomes greater than at the interior. The heating is further increased by the fact that the resistance of the hot metal is greater than that of cold metal.

The enormous electric currents used in this welding process sometimes reach 50,000 ampères, but with an electro-motive force of half a volt, and therefore not capable of giving any sensation to a person.

It would be injudicious to offer any premium upon ignorance, but the operation of electric welding is one of the simplest of mechanical processes, requiring but little skill on the part of the operator in comparison with that exact training of hand and eye and long experience necessary for ordinary welding. The operator must understand the color of the proper welding heat of the metal under treatment, but this is readily learned. The work is not manipulated during the process, except when it is desired to reduce the burr at the weld, and is at all times under observation, and its

heat subject to entire control by means of a lever which graduates the strength of the current.

The dynamo generating the electricity is self-regulating and requires no attention except for lubrication.

There is no unnecessary waste of fuel, the heating being local, and does not extend far from the weld; cotton-covered wire one-fourth of an inch in diameter can be welded without searing the insulation over three-fourths of an inch from the weld.

The time for making a weld varies from a fraction of a second to about two minutes, according to the work, although nothing over two inches diameter has yet been welded; but larger machines are in process of construction.

It is not necessary to provide power fully equal to the maximum demand, as the time is so short that the momentum of a flywheel will serve the same purpose as in a drop press, and give up the surplus energy required.

The power is inversely porportional to the time, and appears to be about proportional to 2.3 power of the diameter in inches, with a slight variation of quick work caused by differences in the rates of the thermal conductivity of the material.

Applications.—The process is far cheaper than that of hand welding, and also extends to other methods of manufacture, but the comparative expense differs according to the previous conditions in every place where it has thus far been applied.

Its applications in practical work thus far have been chiefly confined to butt-welding for many purposes, such as continuous wire work, carriage work, axles and tires, cotton-bale ties, barrel hoops and wire cables and many miscellaneous purposes. Axes are made of drop forgings, joining the tool steel edge to a mild steel poll; bars are heated in the middle and upset, forming collars, and pipes are joined together—a matter of great value in ice machines. The list might be continued to greater length, but this indicates the range of its practical uses at this early day.

Strength of Electric Welds.—The value of the process, for most purposes, independent of any scientific interest or mechanical in-

genuity shown in the apparatus, must be that of the resistance of the welds under tensile stress.

It will be readily understood, however, that as this process accomplishes many things hitherto impossible, aside from any question of ultimate strength, it is fitted for applications in many constructions where it saves labor and time, provided only that the joints be in all cases sufficiently good for the purpose for which the article is designed. A large field thus opens up in the execution of ornamental design in metal work, where it will supplant screws, rivets or solder for fastenings, and in other evident applications.

Under the name "electrohephestos" MM. de Bernados and Olszewsky have patented a new method of electrically welding metals, especially parts of iron. This method, according to "Dingler's Polytechnical Journal," is in a certain sense a complement to Prof. Thomson's process. While the latter brings the pieces of metal to be joined to a welding heat and unites them by the use of pressure, thus forming an actual weld, Bernados and Olszewsky melt the two metals at their juncture, whereby a soldering together is effected.

Extensive experiments with Bernados and Olszewsky's electric welding apparatus have recently been made at Tegel, near Berlin. The process is described as follows: The joint of the two metals which are to be welded together is connected with the negative pole of a dynamo or other source of supply, the positive pole of which is formed by a carbon pencil. Under the intense heat of the arc the most refractory metals melt almost instantaneously at their junction and fuse together. But the action is purely local, like that of a blow-pipe, and only those parts upon which the arc plays directly are attacked, the adjoining portions undergoing little change, and the fused mass solidifying and cooling very quickly. The slightness of the chemical change produced by the action of the arc at the joint is shown by the appended table:

Composition of material.	Steel.		Iron.	
	Before welding.	After welding.	Before welding.	After welding.
Carbon	0.48	0.25	0.34	0.14
Silicon	0.04			
Manganese	0.50	0.25	0.50	0.23
Sulphur	0.04	0.04	0.14	0.09
Phosphorus	0.08	0.07	0.12	0.11
Iron	98.86	99.30	98.90	99.43

The material requires little or no preparation. Even a pretty thick layer of oxide will be reduced and drop off, while smaller quantities of oxide unite to form a slag with the sandy clay frequently added as flux. This slag prevents the oxidation of the metals while cooling. No other fluxes are required. The operations can also be carried on under water, although the gases and steam generated cause trouble. Nevertheless, an apparatus has been constructed to facilitate such work by forcing the water away from the parts to be treated by means of compressed air. One of the chief advantages claimed for the new process appears to be that the arc is brought to the work, and not the work taken to the arc, which would mean transformers, crucibles, or other apparatus. Size is hence a question of secondary importance, and unwieldy pieces may be dealt with, although for soldering work of the ordinary kind a special operating table is employed as more convenient.

In order to obtain the various strengths of current and E. M. F. necessary when operating upon pieces of different size storage batteries are employed which have been especially constructed for this purpose by M. de Bernados. The complete cell, Fig. 25, weighs 35 lbs. and contains nine lead plates, Fig. 26, all of the same kind, four of them positive and five negative, with 1½ square yards of total surface. Each plate consists of a frame cast of pure lead 6 × 7¾ inches surface and 0.2 inch thick. The interior of the frame

is filled with strips of thin lead, alternately straight and corrugated, Figs. 27 and 28, soldered into their places; the latter strips are bent in such a manner as to facilitate upward currents in the liquid. The cells have an interior resistance of 0.002 ohm and give 2.5 volts when continually charged while at work. Fifty to seventy of these cells are joined in a battery; several batteries, three for instance, are grouped in parallel and are continually charged by a shunt dynamo. The diagram, Fig, 29, explains the ordinary connections. The shunt dynamo charges the fifty accumulator cells in series; a voltmetre and an ampèremetre are inserted at *V* and *A*. From the positive terminal of every fifth cell a wire leads to a plug switch-board *U*; from *U* the current passes through a variable resistance *W*, and from thence through a flexible cable to the carbon-holder *Z* and the carbon pencil *K*. The operator manipulates this carbon-holder *Z*, the metal to be fused placed upon the table *P* being joined directly to the negative terminal of the battery. By inserting the plug in the switch-board *U* the operator may obtain currents from five cells, and so on to ten times five cells. If considerable masses of metal are to be dealt with, currents of considerable strength are needed. These are obtained by grouping the batteries of certain sets of cells in parallel. Supposing the dynamo gives a current of 175 volts and 120 ampères, that there is a battery of seventy cells coupled in series, and that it is desired to solder two boiler plates of $\frac{2}{5}$ inch thickness. The carbon-holder is connected with the positive terminals of the fortieth cells of three groups. The carbon is allowed to touch for a fraction of a second, and is taken off immediately, so that between the plates and the carbon pencil an arc of a few millimetres' length is formed. The iron melts like wax, but the action seems too powerful, the molten metal hissing and evaporating distinctly. In such a case one of the three parallel groups is cut out. Should the action then be too sluggish, one or more parallel groups is added. Sometimes the arc proves too small or extinguishes frequently; in such cases the number of cells in each group has to be increased.

The carbon-holder (Fig. 30) resembles a pair of scissors, and consists of two copper bars having a round hole near the end, in

Fig 25
Fig 26
Fig 27
Fig 28
Fig 29
Fig 30
Fig 31
Fig 32
Fig 33
Fig 34
Fig 35
Fig 36
Fig 37
Fig 38
Fig 39

which the pencil is held firmly, either by the friction of the parts or by means of a little wedge, as shown in the illustration.

One of the most important applications of the new process is for welding plates of all thicknesses. For the very finest sheets of one millimetre and less, the Electro-Hephestos Company prefer a modification of Prof. Thomson's process. But all stronger plates up to several centimetres thickness are subjected to the arc.

To effect this with ordinary plates, the edges are feathered as in Fig. 31, or Fig. 32, and pressed together. The furrows are filled with little pieces of the same material, and the arc is then applied, while fresh pieces are added until the furrow is completely filled with the molten mass. The plates are immediately afterwards finished under the hammer. In making iron welds the small pieces for filling are always of wrought-iron. With iron a flux of clay sand is recommended; with copper, borax or sal-ammoniac. The arrangement (Fig. 32) secures great strength, but is of course only applicable when the lower surface of the metal can be got at. When the plates are joined on their lower surfaces, M. de Bernados suggests a powerful electro-magnet placed as indicated in Fig. 33 to prevent the liquid metal (provided the material be para-magnetic) from flowing off. The apparatus shown in Fig. 34 looks more practical; it is intended to be employed when making vertical seams. The pincers carry two pieces of graphite or coke, forming a sort of chamber at the spot where the fusion is to be effected. As soon as the mass has hardened sufficiently the carbon pieces are pushed further up. Carbon pieces are frequently employed to prevent the flowing off of the fused material. Figs. 35 to 39 exemplify other ways of joining plates in cases where a perfectly straight surface is not insisted upon; for thinner plates the method, Fig. 39, seems to offer particular advantages; for two one-fifth-inch plates a seam of a yard length can be made in seven minutes. When plates are to be joined at an angle the process is, of course, exceedingly simple.

This process also permits of the welding of dissimilar metals, so that iron and copper, zinc, steel, cast-iron, etc., can be united.

XVI.

WIRE—MANUFACTURE, BRASSING, COPPERING, ELECTROPLATING, GALVANIZING, ETC.

The process of wire-drawing consists in pulling cold metallic rods through perforated plates or "blocks," presenting a series of tapering apertures of decreasing areas, and whereby the rods are increased in length at the sacrifice of thickness. The ratio of attenuation is directly according to the squares of sectional diminution; for example, by reducing a rod, say, one-half, one-third, or one-fourth, etc., in diameter, its length is respectively augmented four, nine or sixteen times. Iron and steel wires are usually drawn through steel-plates, but those of the precious metals required for the more accurate purposes of science or the arts are commonly drawn through perforated diamonds, rubies, or other hard stones suitably mounted in the "blocks," and whereby great lengths of fine wire can be produced of uniform section. For a long period iron wire was very largely produced and almost exclusively used for many purposes, but, for the last fifteen years or so, steel has superseded its employment for numerous appliances, and to a marked extent.

The drawing properties of metals are dependent upon the combined degrees of tenacity and ductility—that is, the resistance possessed by any body to the separation of its parts, and the capacity for change of form under the influence of tension or squeezing pressure respectively. Gold, platinum, silver and iron range highest in ductile notation; whilst lead, tin and zinc are lowest. Tenacity has more influence upon ductile efficiency than upon the malleability of metals. The various uses to which different wires are and may be applied are too numerous to define, but amongst the most important, as measured by quantity used, are the following: For ropes for marine, mining, railroad and agricultural purposes; for fencing, musical, bottling, bale-tying, brush-making, carding, upholstering, netting, electrical engineering and other manufacturing and scientific purposes. With the exception

of those employed for electrical and scientific purposes, the wires would be chiefly composed of iron and steel. The qualities of these wires are commonly defined by such prefixes as charcoal, iron wire, Bessemer, basic, Siemens and crucible, etc., steel wires, and these may be further characterized by the qualifications—black, bright, annealed, improved or patented, galvanized, tinned, coppered, etc. The first-named distinctions simply denote the processes by which the steel has been manufactured, whilst other trade conventional names indicate certain purposes to which the wire is considered particularly applicable, for instance, "plough steel," which is steel wire of high tensile strength. Close attention is given to the chemical composition of the ingots or blooms from which the billets and wire rods are rolled. This composition varies to a known or determined extent, according to the rods to be manufactured; it is a branch which is more or less justly considered one of the secrets of the industry. As a general statement it may, however, be accepted that the various characteristics of the different rods are mainly dependent upon the amount of carbon present, and the proportionate admixtures with phosphorus, sulphur, silicon and manganese. When carbon is present to the extent of 0.75 to 1 per cent., the metal exhibits remarkable tensile properties and capabilities for tempering, also an ocult process in the trade which has become quite an art; for upon the skill and judgment with which this operation is conducted the excellency of the wire largely depends. The requisite elimination or absence of sulphur, phosphorus and silicon, is another important consideration, for if present to any improper extent the steel cannot be worked with a maximum amount of carbon, whereas manganese favors the presence of the latter. For different purposes the amount of carbon present in steel rods may range between, say 0.075 and 1 per cent., and their hardness and tensile resistance increase in accordance with such proportions. The appreciable presence of sulphur and phosphorus is generally highly deleterious, because they produce "shortness" and unsoundness. Whilst excess of silicon may impart similar properties and brittleness dependent upon the amount of carbon present, phosphorus in any quantity is an enemy to

ductility and the process of tempering. From the above remarks it will be evident that good wire rods can be and are produced from suitable crucible steel, and from Siemens, Martin and Bessemer steel. The following are the approximate breaking strengths of various wires in tons per square inch:

Annealed iron wire,	25 tons per sq. in. tensile resistance.
Bright ditto,	35 " " " " " "
Bessemer and basic steel wire,	40 " " " " " "
Mild Siemens steel wire,	60 " " " " " "
Crucible cast-steel wire,	80 to 90 " " " " " "
Patent plough, crucible, ditto,	100 to 120 " " " " " "

Wire rods are now commonly rolled from blooms, 4 inches to 10 inches square, or billets, of about 2 inches square, of from 50 to 150 lbs. each. At Garrett's wire-rod mill, near Chicago, Ill., rods are rolled direct from 4-inch blooms of 120 lbs. each, and finished in one heat, the average production per shift of 11 hours being about 60 tons, and the largest week's work about 770 tons. In a large wire-rod mill in England the billets used weigh mostly from 120 to 150 lbs. each; but even 200 lbs. can be manipulated at one heat. Unlike rod mills of the ordinary or old construction, which have the hot rods received on either side of the rolls by hands, which pass them to and fro, the machine used in these works is of more continuous action, and hands are only required on the one side of the mill to feed the top set of rolls, and the rods are automatically returned through a lower series. The mill is driven by straps and a suitable gearing, so as to impart a suitable velocity to each succeeding set of rolls, in order to pick up the slack or increasing lengths caused by rolling out the rods; the same effect may also be obtained by varying the diameter of the rolls. The peripheries of the rolls are provided with the decreasing V, U, and semicircular grooves, for the purpose of squeezing out and kneading the metal into as compact and homogeneous a form as possible as it passes through them. The various rolls are capable of accurate adjustment to insure each set reducing the rod to the required diameter, and the last of the series rolling exactly to a desired gauge.

Rods are usually rolled down to a No. 5 English legal standard wire gauge, but for smaller sizes of wire they are sometimes reduced to a No. 8 gauge in order to diminish the labor of wire-drawing and also effect a saving in the annealing department. During the rolling process before described the metal may be squeezed through, say, twelve or fifteen sets of rolls, *i. e.*, a dozen or more consecutive "passes" are commonly made from the billet to the finished rod at one, two or more heats, according to the efficiency of the mill and general arrangements. Fig. 40 shows the entire series of grooves of a wire-rod roll. The construction

Fig. 40.

of an oval groove will be seen from Fig. 41. The width of the groove b is the diagonal of a square, from the corners of which the two arcs are described which terminate the oval groove. It is then $b = 1.414\ r$, and $h = 0.5858\ r$.

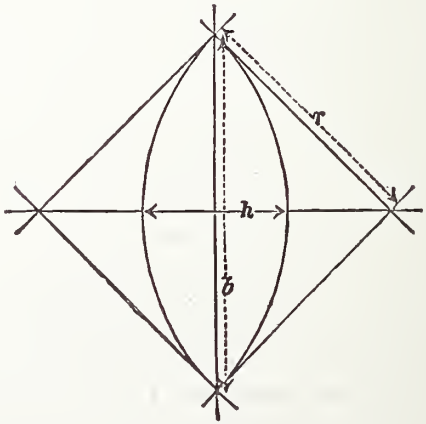


Fig. 41.

During the process of rolling the particles or molecules of the metal are more or less squeezed or forced into abnormal positions,

thus impairing the uniform temper of the rods; but this, however, is commonly counteracted by subsequent annealing or reheating, so as to allow the molecules to resume their normal relations. The length of finished rods may vary from 60 to 150, and up to 500 yards in one piece, naturally dependent upon the gauges, materials and weights they are produced from. For example, a No. 5 gauge rod, 0.212 in. in diameter, rolled from a billet weighing 1 cwt., would be about 320 yards in length, and this, if subsequently drawn down to No. 20 gauge wire, 0.036 inch in diameter, would equal some 11,200 yards in length, without any appreciable diminution in weight. The gauge referred to is in all cases the "English legal standard."

After the rods leave the "blooming mill" they are taken to the "wire mill," where they are hung around wooden blocks, perhaps half a dozen coils on each block, which are lowered into huge tubs of sulphuric acid, and allowed to remain there until the acid has removed the impurities from the surface. The blocks are then raised by a pulley, and the rods are thrown upon the floor and washed with the hose. Having been loaded on trucks and dried, one end of each rod is pointed by a revolving machine so as to obtain tapering rods capable of being introduced into the conical apertures in the draw-plate. In some cases the rods after having been freed from impurities are dipped in lime-water, which assists the process of drawing, and finally are placed in a drying room or chamber.

A wire-drawing mill consists of a series of horizontal drums or pulleys—termed "blocks"—mounted on vertical axes upon long benches with draw-plates and pincer devices attached to each. The draw-plates, which are pierced with a regular gradation of tapering holes, are held in vices or clamping frames firmly fixed to the bench, whilst the mechanical pincers are provided for catching hold of the tapering extremities of the rods inserted in the holes of the plates for pulling them through, the pairs of pincers being forced back by revolving cones fixed on the drum spindles. When a sufficient length of any rod has thus been drawn to enable a turn being taken round a revolving pulley or drum, the drawing process

is continued by this means, the turning of each of the series of pulleys drawing one of the various rods through the steel plates or draw-blocks, and thereby increasing their lengths by reducing their thickness.

Fig. 42 represents a wire-drawing mill. *A* is the reel upon which the wire is wound; *b* the draw-iron held in the frame *B*, the finely hatched portion consisting of steel. *C* is the drum. The shaft *f* with the pulley *i* revolves constantly, whilst when running empty the drum stands still. When the drum is to revolve, it is lifted up by means of a treadle at *f;* the hook *o* catches the drum and takes it along. When the wire *c*, which winds up spirally, has

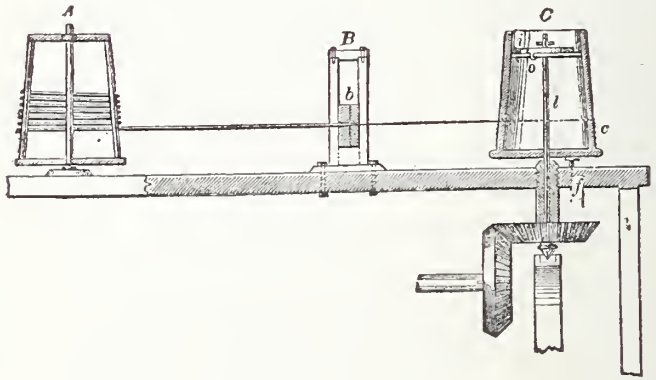


Fig. 42.

entirely passed through the draw-iron the tension ceases, the drum falls down, and, being liberated from the hook *o*, comes to a standstill without the co-operation of the workman.

The wire drawn upon any drum may have to be re-drawn in a similar manner a number of times dependent upon the gauge required, the process being facilitated by the application of lubricants, termed "wire-drawers' soap and grease," as the wire is pulled through the decreasing holes in the draw-plate. Lubrication, as commonly practised, consists in applying a paste made of wheat flour or lime to the surface of the wire to be drawn, and when the paste is dry to smear the wire with tallow or grease; the wire

is then ready to be drawn, the dried paste serving to prevent the lubricant from being pressed out in the process. Some manufacturers use in drawing fine wire a lubricant consisting of sour beer yeast and a layer of olive oil. F. Vogel recommends the following fat pickle: Melt a determined quantity of lard or similar substance, and after cooling it to about 125° F. add, with constant stirring, 20 to 40 per cent. of 66 per cent. sulphuric acid until the mass is of the consistence of soft soap; then, with continued stirring, add water until the mixture is completely dissolved in the water. By adding sulphuric acid as well as water the mass becomes again heated, and hence sufficient provision for cooling must be made. The application of this very fat fluid lubricant is claimed to facilitate the drawing of wire to such an extent that annealing during drawing is not so often required as in the ordinary process. It is further claimed that the draw-irons do not wear out so quickly, that the wire acquires a higher lustre and does not rust so readily.

Chas. H. Morgan recommends the use of a hot solution of lime and salt as a lubricant in drawing Bessemer wire. By using the solution at a boiling temperature the water is quickly thrown off, when the wire is taken from the bath and kept in a warm dry place until it is drawn. Salt coating, whether combined with lime or otherwise, is claimed to resist any pressure that steel wire of the highest tensile strength makes, when being drawn, upon the inner surface of the die.

As the drawing operations proceed the wire becomes proportionally hardened and its original properties altered so that it has to be annealed at certain stages of the process. In practice wire to be drawn to a fine gauge is sometimes returned to the annealing pot about half a dozen times. During the process of drawing some wire may be placed on reels mounted in tubs of acid and other solutions for cleaning off any coat of oxide formed by annealing. The annealing pots are simply metal chambers into which the wire is placed and hermetically sealed during the process of heating for several hours at a red heat, and which afterwards is allowed gradually to cool down. An average-sized pot receives about 50 per

cent. of wire at one charge. Finally annealed or tempered wires are always softer and more pliable than those bright-finished or drawn; steel wire, however, requires different treatment from that employed for iron. To avoid the formation of scales during annealing, which cannot be entirely prevented, even with the use of hermetically sealed pots, W. Rath immerses the wire before annealing in a solution of calcium chloride of the consistence of syrup. The protecting coat which is thereby formed upon the wire is removed after annealing and cooling by rinsing in clean water.

The drawing-drums before referred to are of various sizes—say from 32 inches to 10 inches diameter, and may be driven at a speed of about 300 to 400 feet per minute for ordinary wire; steel wire should be drawn at a slower speed in order to prevent breakages. The drums used for taking the first draws on the rough rods are termed "ripping blocks" and are of large diameter and strong construction, whilst the speed of driving is usually rather lower than that above mentioned; but this, however, is dependent throughout upon the sizes of the blocks and the classes of wire to be drawn. The drums of small-sized blocks may be driven at a velocity of 500 feet or more per minute for drawing soft wire. When the holes in the drawing-irons have become enlarged by wear the plates are heated and hammered up and partially re-punched, the requisite diameters of the holes being ascertained and adjusted by the insertion of gauge punches. Some kinds of wires are tempered or "patented" before drawing; others during or after this process, in order to promote or develop a uniform temper or flexibility, and few processes are conducted less according to fixed rules or with more secrecy, as nothing but experience can initiate one into this important branch of the industry. In every case, however, it is necessary that the rods or wire be raised to a definite temperature in a furnace chamber or "muffle" before the cooling and fixing process is commenced, and which is somewhat determined by the colors the metal assumes by oxidation during the progress of treatment.

The finally prepared wires of the required gauges are then

formed into bundles or coils of convenient dimensions and removed to the store-room ready for transport or use.

As regards wires from other metals than iron and steel it remains to be said that they are generally drawn from small square blocks cut from sheet. The strips are rounded off in the draw-iron and gradually drawn out to the desired diameter. Annealing is more or less required with all metals; copper requires but little, it being very ductile.

Half-round Wire.—Schniewindt produces half-round wire by splitting round wire by means of rotatory shears. The wire is wound upon a reel *a*, Fig. 43, and passes through the rolls *b*,

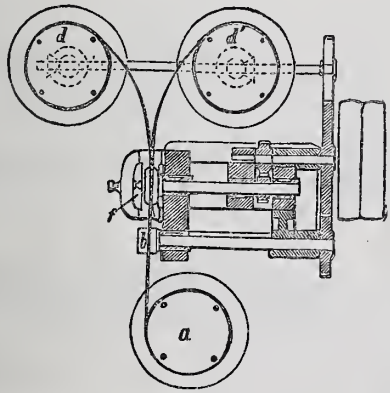


Fig. 43.

which are provided with corresponding grooves to a guide *f*. The latter feeds the wire to the circular knives in such a manner that it is cut through longitudinally in the direction of its axis and wound upon the two receiving reels *d* and *d'*.

Barbed Wire.—This variety of wire consists of wire cords, or even single wires, provided with projecting sharp barbs placed at short distances from each other. It is at present much used for fencing of all kinds. As regards shapes and dimensions barbed wire varies very much; a number of typical shapes are shown in Fig. 44. Varieties *A* to *C* consist of two galvanized steel wires

0.098 inch in diameter, which are twisted into a cord and provided with sharp-pointed barbs. The latter are formed of a piece of wire cut obliquely on both ends and wrapped twice around the cord. On *A* the barbs are 4¾ inches apart, on *B* 2½ inches, and on *C*, which is provided with four barbs, 5¾ inches. Variety *D* consists of three steel wires, between which are placed sharp sheet-steel-points projecting in all directions, there being about 24 such

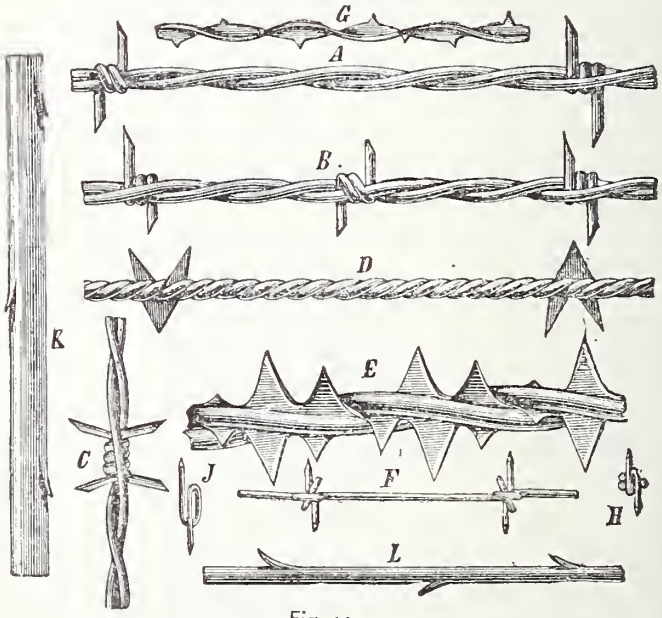


Fig. 44.

points for every 3¼ feet. *E* shows barbed fencing wire manufactured by Bernhard Ebeling, of Bremen. It consists of two steel wires 0.098 inch in diameter twisted together and provided throughout their entire length with an insertion of a strip of notched hoop-iron. Another variety manufactured by C. Klauke, of Müncheberg, near Berlin, consists of a single wire only. It is made by a machine especially constructed for the purpose. A short piece of wire is

first shaped as shown in *J*, Fig. 44, which is then connected with the principal wire in the manner illustrated by *F* and *H*. This arrangement is inferior to the shapes *A* to *D*, the wire being less solid and the barbs pointing only in two directions.

Moen has patented a machine for the manufacture of barbed wire, which is shown in Fig. 45. Around a wire is wrapped a strip of sheet-iron, one edge, or both edges, of which is provided with oblique incisions which, in wrapping and bending the strip of sheet-iron, form the barbs. The strip of sheet-iron rolled up is placed upon the wrapping contrivance *R* and reaches by means of the guide *v w* the progressing, but not revolving wire. *N* and *O* are

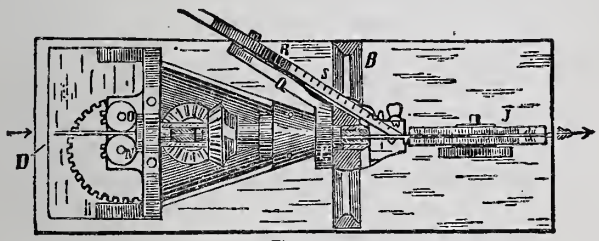


Fig. 45.

conducting rolls, *B* is the drum for impulsion and is connected with the arms *P* and *Q*, while *J* is the drum for carrying away the finished barbed wire.

Barbed wire has also been manufactured from a single wire without any addition. Fig. 44 *G* shows such a barbed wire consisting of spirally twisted hoop-iron the edges of which are provided with sharp incisions, which in twisting form projecting barbs. Finally the "Westphälische Union," of Hamm, manufactures an oval wire 0.31 inch wide and 0.11 inch in diameter, which, as shown in the illustrations *K* and *L*, Fig. 44, is provided on the sides with sharp incisions. By turning up the points thus made barbs are formed which are, however, rather short, stand quite obliquely and only alternately on two sides.

Barbed wire is brought into commerce wound upon a wooden reel.

Phosporized Bronze or Brass Wire.—Whiting, of Manchester, England, manufactures phosphorized bronze or brass wire by immersing stout wire of the above-mentioned or other alloys in a solution of 0.125 to 5 per cent. of phosphorus in ether, bisulphide of carbon or olive oil, 5 to 10 per cent. of sulphuric acid and 85 to 95 per cent. of water, whereby, it is claimed, the metal absorbs phosphorus. The wire is then drawn one number finer and brought into a closed retort, the bottom of which is covered with a thin layer of phosphorus, so that the vapors of phosphorus evolved can pass over the wire. The latter is then packed in charcoal, and the charcoal being ignited the wire is kept in the heat until sufficiently softened to allow of being drawn one number finer. Wire thus repeatedly treated is claimed to possess great resisting power and acquire a high polish.

Hardening of Wire.—Frequently it is desirable to harden wire, especially steel-wire, in coils. For this purpose the coil is placed upon a reel from which the wire is conducted in a horizontal direction to and wound upon a second reel placed at some distance from the first. In its passage to the second reel the wire passes through between a pair of plates 4 to 6 feet long, lying in a furnace and kept at a red heat, and is next conducted through between a similar pair of plates cooled by water. The plates of each pair are provided with suitable grooves for the reception of the wire; a third pair of plates is moderately heated and serves for tempering to the desired degree of hardness. Instead of the centre pair of plates a reservoir filled with water or oil is sometimes used for cooling.

Ramsden's Method of Hardening Wire differs somewhat from the above. The wire is conducted through pipes, in which it is heated by the flame of an inflammable mixture of carburetted hydrogen gas and steam, and then passes into a cooling bath.

For heavier wires two small pipes are arranged at a right-angle to each other, the one being placed in a horizontal and the other in a vertical position, and their mouth-pieces provided with narrow apertures. The free end of the horizontal pipe connected by means of a cock or valve with a steam-pipe, and the lower end of the

vertical pipe with a vessel filled with a hydrocarbon, for instance, paraffine or petroleum. A current of steam being conducted through the horizontal pipe absorbs, in passing by the mouth-piece of the vertical pipe, carburetted hydrogen and carries it along in a finely divided state and intimately mixed with the steam. Of such pairs of mouth-pieces a sufficient number for the production of the necessary degree of heat, which can be regulated by a cock, are arranged in front of a cylinder lined with fire clay, so that the flame entirely freed from smoke and other injurious substances passes through the chamber into the chimney. Now if the chamber is about 13 feet long the heat, where the flame enters, will be considerably greater than where it passes out, and thus the apparatus can be used in the front part for hardening and in the back part for tempering. The chamber rests upon a vessel divided into two parts, one division of which may be filled with cold water or a frigorific mixture. The wire being unwound from a reel passes through the front part of the chamber, and after being conducted through the fluid is again wound upon a reel. For tempering the wire may then be conducted through the back part of the chamber, and from there into the other division of the vessel, which contains water, oil or a suitable fatty mixture.

For finer wires and such as are not to come in contact with the flame a pipe of fire-clay about 13 feet long is used; it may be without a partition, or divided into an upper and lower chamber. In the latter case, the lower chamber is heated while the wire passes through the upper. When coming from the latter it is struck by a jet of oil or other suitable fluid, and tempering is effected by immersing it in a bath of a suitable boiling fluid, for instance linseed oil at 536° F., or mercury at the same temperature, or in melted lead, the adhering lead being, in the latter case, removed. Fig. 46 *I* shows the arrangement for coarser and *II* and *III* for finer wires. On the chamber of the first the mouth-pieces *B* and *C*, provided with the cock *D*, connect with the reservoir of carburetted hydrogen *E* and the steam conduit; *G* is the reel upon which the wire to be hardened is wound. The wire *W* passes through an aperture into the front part of the chamber, which is

strongly heated, then underneath the first roll F over a second roll, through an aperture in the bottom of the chamber into the division beneath and finally upon the reel G_1, the latter dipping into the reservoir H, which is filled with water or a refrigorific mixture. The wire while passing the two rolls F in the chamber A_1 is heated and hardened by dipping in the fluid in H. To facilitate the conducting of the cold wire over the rolls F, before the chamber is heated, apertures A_1, for passing the rolls through, are provided on the upper portion of the chamber, which, after the wire is placed in position, are closed by the lid A_1. The superfluous heat is conducted away from the chamber A through the chimney P, and the reel G_1 with the hardened wire is taken from the reservoir H and placed in K over the chamber A. From here the hardened wire W passes into the rear or chimney end of the chamber A_1, in which the heat, having been moderated by the bridge J, is much less, but sufficient to heat the wire running over the rolls F_1 for tempering. The wire is then wound upon the reel K which dips into the oil in the reservoir H, whereby the wire is tempered.

For finer kinds of wire the retort or heating chamber M, Fig. 46 II to IV, is divided lengthwise into two parts by the partition N. On the front side of the chamber are apertures O_1, opposite to each a pair of mouth-pieces is arranged. The flame entering at O sweeps along the lower side of N through the holes C into the upper part of the chamber. The wire is introduced into the upper part of chamber at the end S_1 and heated while passing through it. The heat is retained in the upper portion of the chamber by the lids L. These lids are arranged on each end of the upper chamber so as to leave room to allow of the passage of the wire. On leaving the retort the wire is hardened by dipping in a current of oil running over the sloping plate S. The oil flows uninterruptedly from the pipe T, which is connected to a reservoir, runs over the sloping plate S into the holder T_1, and from there is pumped back into T. The hardened wire, in order to acquire the necessary temperature, then passes through a bath U of linseed oil, mercury or lead, which is heated by a fire. After passing through the bath

U it is wound upon ordinary reels arranged in a suitable position near the bath *U*. To facilitate the introduction of the cold untempered wire into the retort before heating, a channel or gutter is provided on the upper side of the retort. The wire is conducted through this channel or gutter, which, later on, is closed by the lid

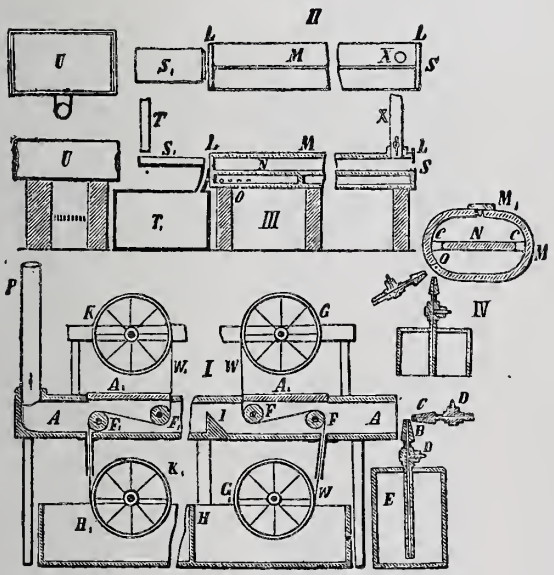


Fig. 46.

M_1. The superfluous heat is conducted away through the chimney *X*.

The following tables relating to wire are furnished by John A. Roebling's Sons Co., of Trenton, N. J.

Wire Gauges,

In Decimal Parts of an Inch.

Number of wire gauge.	Roebling.	Brown & Sharpe.	Birmingham, or Stubs.	English Legal Standard.	Old English, or London.
000000	.46	.....	.....	.464	
00000	.43	.....	.....	.432	
0000	.393	.46	.454	.4	.454
000	.362	.40964	.425	.372	.425
00	.331	.3648	.380	.348	.38
0	.307	.32495	.340	.324	.34
1	.283	.2893	.3	.3	.3
2	.263	.25763	.284	.276	.284
3	.244	.22942	.259	.252	.259
4	.225	.20431	.238	.232	.238
5	.207	.18194	.22	.212	.22
6	.192	.16202	.203	.192	.203
7	.177	.14428	.18	.176	.18
8	.162	.12849	.165	.16	.165
9	.148	.11443	.148	.144	.148
10	.135	.10189	.134	.128	.134
11	.12	.09074	.12	.116	.12
12	.105	.08081	.109	.104	.109
13	.092	.07196	.095	.092	.095
14	.08	.06408	.083	.08	.083
15	.072	.05706	.072	.072	.072
16	.063	.05082	.065	.064	.065
17	.054	.04525	.058	.056	.058
18	.047	.0403	.049	.048	.049
19	.041	.03589	.042	.04	.04
20	.035	.03196	.035	.036	.035
21	.032	.02846	.032	.032	.0315
22	.028	.02534	.028	.028	.0295
23	.025	.02257	.025	.024	.027
24	.023	.0201	.022	.022	.025
25	.02	.0179	.02	.02	.023
26	.018	.01594	.018	.018	.0205
27	.017	.01419	.016	.0164	.01875
28	.016	.01264	.014	.0148	.0165
29	.015	.01125	.013	.0136	.0155
30	.014	.01002	.012	.0124	.01375
31	.0135	.00893	.010	.0116	.01225
32	.013	.00795	.009	.0108	.01125
33	.011	.00708	.008	.01	.01025
34	.01	.0063	.007	.0092	.0095
35	.0095	.00561	.005	.0084	.009
36	.009	.005	.004	.0076	.0075

Table Indicating Size, Weight, and Length of Iron and Steel Wire.

Gauge number.	Diameter. Inches.	Weight of 100 feet. Pounds.	Weight of one mile. Pounds.	Feet in 2000 pounds.	Area. Square inches.
3–0	.362	34.73	1834	5,759	.102921
2–0	.331	29.04	1533	6,886	.086049
1–0	.307	25.00	1318	8,000	.074023
1	.283	21.23	1121	9,425	.062901
2	.263	18.34	968	10,905	.054325
3	.244	15.78	833	12,674	.046759
4	.225	13.39	707	14,936	.039760
5	.207	11.35	599	17,621	.033653
6	.192	9.73	514	20,555	.028952
7	.177	8.30	439	24,906	.024605
8	.162	6.96	367	28,734	.020612
9	.148	5.80	306	34,483	.017203
10	.135	4.83	255	41,408	.014313
11	.120	3.82	202	52,356	.011309
12	.105	2.92	154	68,493	.008659
13	.092	2.24	118	89,286	.006647
14	.080	1.69	89	118,343	.005026
15	.072	1.37	72	145.985	.004071
16	.063	1.05	55	190,476	.003117
17	.054	.77	41	259,740	.002290
18	.047	.58	31	344,827	.001734
19	.041	.45	24	444,444	.001320
20	.035	.32	17	625,000	.000962
21	.032	.27	14	740,741	.000804
22	.028	.21	11	952,381	.000615
23	.025	.175	9.24	.....	.000491
24	.023	.140	7.39	.....	.000415
25	.020	.116	6.124	.....	.000314
26	.018	.093	4.91	.....	.000254
27	.017	.083	4.382	.....	.000227
28	.016	.074	3.907	.....	.000201
29	.015	.061	3.22	.....	.000176
30	.014	.054	2.851	.....	.000154
31	.0135	.050	2.64	.....	.000143
32	.013	.046	2.428	.....	.000132
33	.011	.037	1.953	.....	.000095
34	.010	.030	1.584	.....	.000078
35	.0095	.025	1.32	.....	.000071
36	.009	.021	1.161	.....	.000064

Weight per 1000 Feet of Copper Wire.

Number.	Roebling.	Brown & Sharpe.	Birmingham.	English legal standard.
000000	641.20	.....	.....	652.39
00000	560.29	.....	.....	565.51
0000	468.02	641.20	624.58	484.83
000	397.09	508.49	547.33	419.33
00	332.00	403.26	437.56	366.97
0	285.60	322.79	350.29	318.10
1	242.69	253.61	272.72	272.72
2	209.60	201.13	244.07	230.83
3	180.41	159.49	203.27	192.43
4	153.39	126.49	171.64	163.09
5	129.84	100.31	146.66	136.19
6	111.71	79.54	124.87	111.71
7	94.93	63 08	98.18	93.86
8	79.52	50.03	82.50	77.57
9	66.37	39.68	66.37	62.83
10	55.22	31.46	54.41	49.65
11	43.63	24.95	43.63	40.77
12	33.41	19.79	36.00	32.77
13	25 65	15.69	27.35	25.65
14	19.39	12.44	20.87	19.39
15	15.71	9.87	15.71	15.71
16	12.03	7.83	12.80	12.41
17	8.84	6.20	10.19	9 50
18	6.69	4.92	7.27	6.98
19	5.09	3.90	5.34	4.85
20	3.71	3.10	3.71	3.93
21	3.10	2.45	3.10	3.10
22	2.38	1.94	2.38	2.38
23	1.89	1.45	1.89	1.74
24	1.60	1.22	1.47	1.47
25	1.21	.970	1.21	1.21
26	.981	.770	.981	.981
27	.876	.610	.776	.815
28	.776	.484	.594	.664
29	.682	.384	.512	.560
30	.594	.304	.436	.466
31	.552	.241	.303	.408
32	.512	.191	.245	.353
33	.366	.152	.194	.303
34	.303	.120	.148	.256
35	.273	.095	.076	.214
36	.245	.076	.048	.175

WEIGHT PER MILE OF COPPER WIRE.

Number.	Roebling.	Birmingham.	Brown & Sharpe.	English legal standard.
0000	2466	3286	3375	2555
000	2092	2884	2677	2210
00	1750	2305	2123	1933
0	1504	1846	1684	1682
1	1278	1437	1335	1437
2	1104	1287	1058	1216
3	950	1071	839	1012
4	808	904	665	860
5	684	773	528	718
6	588	657	418	588
7	500	517	332	495
8	419	435	263	409
9	350	350	209	332
10	291	287	166	263
11	230	230	131	215
12	176	190	104	173
13	135	144	83	135
14	102	110	65	102
15	83	83	52	83
16	64	68	41	65
17	47	53¾	33	50
18	35	38	26	37
19	27	28	20¾	26
20	19½	19½	16¼	20¾
21	16⅓	16¼	13	16¼
22	12½	12½	10¼	12½
23	10¼	10¼	8⅛	9¼
24	8¼	7¾	6½	7¾
25	6½	6½	5⅛	6½
26	5	5	4	5
27	4½	4	3¼	4
28	4	3¼	2½	3½
29	3⅝	2⅝	2	3
30	3¼	2¼	1⅝	2½

To Brass Wire in the Galvanic Way.—To carry out this process place the iron rods intended for wire in a bath containing 3 parts of ordinary tin salt to 4 of blue vitriol. The rods must only pass once through the draw-iron and be previously zincked by immersing them for 2 hours in water acidulated with hydrochloric acid in which zinc plates—1 to 1.5 lb. of zinc to 100 lbs. of iron—are

placed. The rods are left in the brass bath for 5 to 6 minutes until they have acquired a dirty reddish color; by passing through the draw-iron they assume a fine straw-color or orange-yellow surface.

To Electro-brass Wire.—A warm bath in an iron boiler lined with sheet brass is used. The sheets of brass are connected to the copper pole of the battery and dipped into the fluid. The bundles of iron wire are first opened, dipped into sulphuric acid, then suspended to a strong wooden peg and scoured with a brush and sharp sand. They are next placed over a strong copper or brass rod resting upon the edge of the boiler and insulated therefrom by means of rubber tubes and connected to the zinc pole by the battery. The wires now receive a coating of copper and then a deposit of brass. As they are only partly submerged in the bath they must from time to time be turned. They are finished by washing and drying in saw-dust. The bath is prepared as follows: Dissolve blue vitriol, 4¾ ozs., and sulphate of zinc, 4½ to 5½ ozs., in 1 gallon of water. Precipitate the solution with 2 lbs. of crystallized soda, decant and wash. Then pour a solution of 1 lb. of soda and 8½ ozs. of sodium bisulphate in 1 gallon of water over the precipitate. Stir the mixture and add commercial potassium cyanide until the fluid becomes clear, when it is filtered off from the suspended ferric oxide. The best temperature for using this bath is between 120° and 140° F.

Brass Wire which may be drawn out to the finest threads is made by placing round rods of copper about 1 inch in diameter and 2½ inches long free in an iron box, upon the bottom of which are laid granulated zinc and sal-ammoniac. By heating the box vapors arise which combine with the copper and superficially convert it into brass. The coating is made as uniform as possible by frequently turning the rods. In this manner copper rods are obtained which, so to say, are plated with brass and may be drawn out to fine wires. The wires have the appearance of brass, but on the cross section the red color of the copper can be recognized.

To Copper Iron Wire.—This process is claimed to prevent the rusting of iron wire; it is partially effected by dipping and

partially by galvanic action. Dissolve at 86° F., 3.38 drachms of blue vitriol in 55 lbs. of water containing 1.12 drachms of sulphuric acid. Pass the iron wire through the cold solution until it is covered with a coating of copper. It is then drawn through an ordinary draw-iron to make the coating of copper adhere more firmly. Repeat the dipping and subsequent passing through the draw-iron several times. Galvanic coppering is effected as follows: Connect the wire to the negative pole of a battery and a copper-plate with the positive pole. As coppering fluid a solution of 39 ozs. of potassium cyanide and 88 ozs. of potassium bichromate in 55 lbs. of water is used; the bath should have a temperature of between 48 and 55° F. By the action of the galvanic current the copper is dissolved from the positive pole and forms the copper solution, from which the copper is deposited upon the wire connected with the negative pole. The coppered wire is passed through the draw-iron. Iron wire may in the same manner be tinned, zincked and coated with lead.

To Galvanize Wire.—The wire, previously made bright by pickling, is passed through a cast-iron crucible containing, according to the quantity and size of the wire, from 40 to 1,000 lbs. of melted zinc, and then passed through the draw-iron to remove the superfluous zinc. The drawing through the bath is effected by unwinding the wire from a reel set in motion by a steam-engine, the velocity depending on the diameter of the wire, it being more rapid with thin wire and slower with thick wire.

An apparatus for this purpose, patented by Roberts, is shown in Fig. 47. *C* is a guide pulley, the block of which is provided with the protecting plate *J*, having a guide slit; it can be shifted on two rods *F*, reaching up to the ceiling of the work-room. On these rods *F* slides a block *E*, with pulley *D*, provided below and above with rope loops. To the lower of these loops is fastened a hand-rope, and to the upper another rope *H*, running over the pulley *G*, which is secured in the ceiling; to the rope *H*, is suspended the counterweight *I*, which, when the running block is on top, stands upon the floor. *P* is a guide pulley resting in a frame. The wire *m* runs from the reel *B* around *C* over *D* and underneath

P into the acid bath, from there into a furnace and the metallic bath, and from here through the polishing machine to the reel upon which it is to be wound. With this apparatus many wires can at the same time be treated.

Vogt has patented an arrangement (Fig. 48) for closing vessels

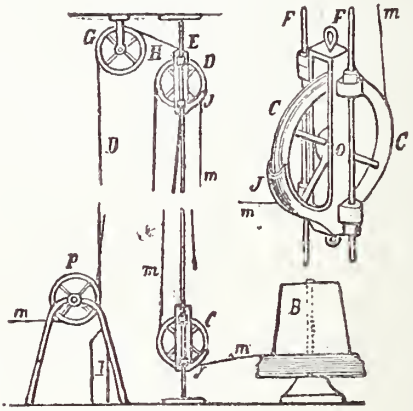


Fig. 47.

through which the wire is to be conducted in a straight direction. It consists of two elastic strips *f*, which, on tightening the screws *g*, are pressed together by the metallic bodies *e*.

For the purpose of removing superfluous zinc Wittle and Kämper have patented the arrangement shown in Fig. 49. It consists of

Fig. 48.

two comb-like plates *a a*, one of which remains stationary during the operation while the other is secured to a rotary lever *c*.

Another apparatus for the same purpose, patented by Roberts, is constructed as follows: Upon the edge of the crucible, where the wire *m* (Fig. 50) leaves the zinc bath, sits an iron box *K*, which is

provided with a slit for the passage of the wire. In the box two rolls L, with longitudinal ribs l, revolving in opposite directions by means of a driving gear placed outside the box. These rolls L are so mounted that two ribs l always come opposite to each other, with sufficient space between them, however, to allow of the pas-

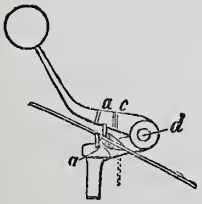


Fig. 49.

sage of the wire m. Outside of the box K are two revolving rolls P, which, by means of the eccentric P', and the sliding rods R, sets the springy stoppers T moving to and fro. To attain the springiness of the stoppers T, they are composed of a rod R', hollow on the end, into which catches the sliding rod B, and the actual

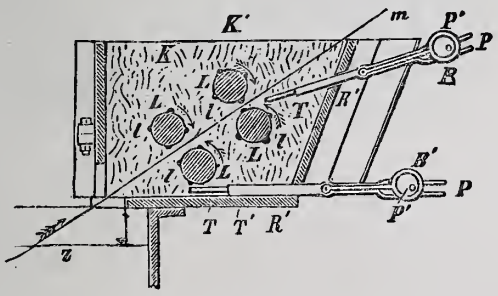


Fig. 50.

stopper T, which slides in a cavity provided with a spring. To prevent the stopper T from falling out it is provided with a pin T', running in a groove. The box K is filled with mineral wool, which by the rolls L is pressed with a certain force against the wire m coming from the metallic bath Z, and thus cleans it.

To Gild Metallic Wire and Wire-cloth.—Fine wire of gilded copper and brass is much used in the manufacture of metallic fringes, and lace for epaulets and other purposes. The fine copper and brass wires being drawn through the drawing, machines and wound upon spools by special machines, and hence not touched by the hands, freeing from grease may generally be omitted. The first requisite for gilding is a good winding machine, which draws the

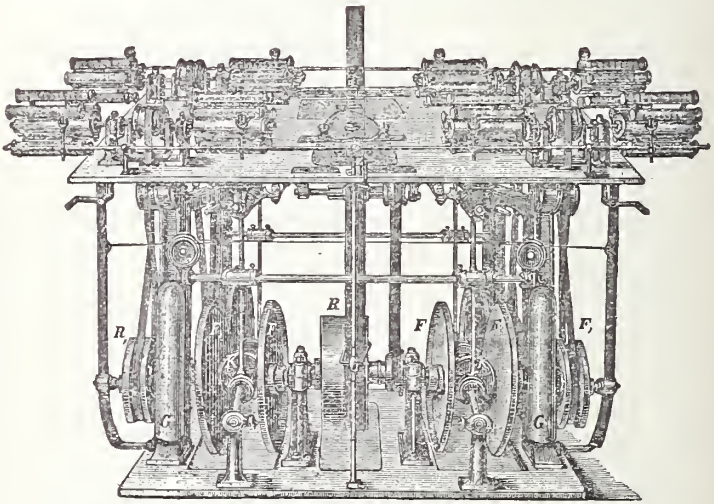


Fig. 51.

wires through the gold bath and wash-boxes, and further effects the winding of the wire upon spools. The principal demand made in the construction of such a machine is, that by means of a simple manipulation a great variation in the speed with which the wire or gauge passes through the gold bath can be obtained. This is necessary in order to be able to regulate the thickness of the gilding by the quicker or slower passage of the wire. A machine well adapted for this purpose is the one constructed by J. W. Spaeth. The variation in the velocity of the passage of the wire is attained by the two friction-pulleys *F* (Fig. 51) which sit upon a common

shaft with the driving-pulley *R*, and transmit their velocity by means of the friction-pistons *K K* to the friction-pulley *F*, which is firmly connected to the belt-pulley *R* driving the spool-spindle. Since by a simple device the pistons *K* and *K* may be shifted, it is clear that the transmission of the number of revolutions from *F* to *F* is dependent on the position of the friction-pistons *K* and *K*, and that the velocity will be the greater the shorter the distance they are from the centre of the friction-pulleys *F* and *F*. In order that the friction between *F K* and *F* may always be sufficient for the transmission of the motion, even when the pistons are worn, four weights *G* are provided, which press the above-mentioned parts firmly against each other.

In front of each spool of this machine is inserted a small enamelled iron vat which contains the gold-bath, and is heated by a gas-flame to about 167° F. Between this bath and the winding machine is another small vat with hot water in which the gilded wire is rinsed.

The wires unwind from a reel placed in front of the gold bath, run over a brass drum which is connected to the negative pole of the source of current, and transmits the current to the wires; the dipping of the wires into the gold bath is effected by porcelain drums which are secured to heavy beams of lead placed across the vats, as shown in Fig. 52. The gilded wire being wound upon the

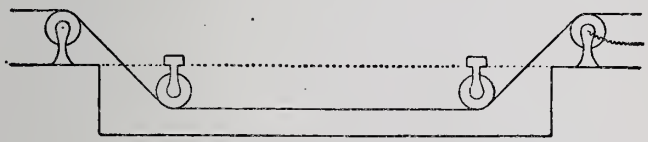


Fig. 52.

spools of the winding machine, these spools are removed and thoroughly dried in the drying chamber. The wire is then again reeled off on to a simple reel, in doing which it is best to pass it through between two soft pieces of leather to increase its lustre. The most suitable formula for the gold bath is as follows: Fine gold in the form of fulminating gold, 15.43 grains; 98 per cent. potassium

cyanide, 77.16 grains; water, 1 quart. The bath is prepared by converting 15.43 grains of fine gold into neutral chloride of gold by dissolving in aqua regia and evaporating, or 29.3 to 30.8 grains of chemically pure neutral chloride of gold are directly dissolved in water; the gold is precipitated as fulminating gold with aqua ammonia, washed out, dissolved in water containing the potassium cyanide and heated, with constant replacement of the water lost by evaporation, until the odor of ammonia disappears. The temperature of the bath should be between 158° and 167° F. Strength of current 6 to 8 volts, which will produce a deposit of sufficient thickness even with the wire passing at the most rapid rate through the bath.

Gold Wire is made by wrapping a very thin sheet of gold around a cylinder of silver, securing it with wire, heating, and, while still hot, rubbing vigorously with the burnisher, and immediately passing through the draw-iron. The ductility of gold is so great that wire as thin as a spider's web appears completely coated with gold when examined under the microscope.

To Nickel Wire.—Nickelling of wire of iron, brass or copper is scarcely done on a large scale; it is, however, believed that the nickelling of iron and steel wires—for instance, piano strings—might be of advantage to prevent rust or at least to retard the commencement of oxidation as long as possible.

To nickel single wires cut into determined lengths according to the general rules is simple enough; but this method cannot be pursued with wire several hundred yards long rolled in coils as it occurs in commerce. Nickelling the wire in coils, however, cannot be done, as only the upper windings exposed to the anodes would acquire a coat of nickel. Hence it becomes necessary to unwind the coil, and for continuous working pass the wire at a slow rate through the cleansing and dipping baths as well as the nickel bath and hot-water reservoir, as shown in Fig. 54 in cross-section and in Fig. 55 in ground-plan.

The unwinding of the wire is effected by a slowly revolving shaft upon which the nickelled wire again coils itself; in the illustration this shaft is omitted. In Fig. 54 four wires run over the four rolls *a*, mounted upon a common shaft to the rolls *b* upon the bottom

of the vat A, whereby they come in contact with a thickly-fluid lime-paste in the vat and are freed from grease. From the rolls *b* the wires run through the wooden cheeks lined with felt, which retain the excess of adhering lime-paste and allow it to fall back into the vat. The wires then pass over the roll *c* to the roll *d*. Between these two rolls is the rose *g*, which throws a strong jet of water upon the wires, thereby freeing them from the adhering lime-paste. The roll *d*, as well as its axis, is of brass, and to the latter is connected the negative pole of the battery or dynamo, so that by carrying the wires over the roll *d* negative electricity is conducted to them. From the roll *d* the wires run over the roll-bench *s* (Fig. 54) to the vat C, which contains the nickel solution, so that they are subjected to the action of the anodes arranged in this vat on both sides of the wires. The wires then pass over the roll *e*, are rinsed under the rose *s*, and run finally through a hot-water reservoir and saw-dust (these two apparatuses are not shown in the illustration), to be again wound into coils. In case a high polish is required the nickelled wires may be run under pressure through leather cheeks dusted with pulverized Vienna chalk.

To Tin Wire and Wire-gauze.—Allow the wire to run slowly into a wooden trough which contains a mixture of 3 parts of water and 1 or 1.75 of hydrochloric acid; then rinse it in water, dry by passing it between two rolls covered with felt or coarse woollen stuff, and finally pass it under a roll placed in a vessel containing strongly-heated tin. To polish the wire coming from the zinc, pass it through between rolls covered with woollen stuff dusted with chalk powder. *Wire-gauze* is pickled in a similar manner, and after rinsing in water the adhering water is removed by wiping with cloths. The wire is then dusted with finely powdered resin inclosed in a bag, the gauze placed upon a frame and immersed in the tin bath, where it remains 1 to 2 minutes, when it is lifted out and the excess of tin removed by shaking the frame. Especially fine tinning of iron wire is produced as follows: Place the wire in a wooden vessel of suitable size, which contains water mixed with 10 per cent. of hydrochloric acid, and upon the bottom of which zinc plates are placed. After a short time a gray coating of

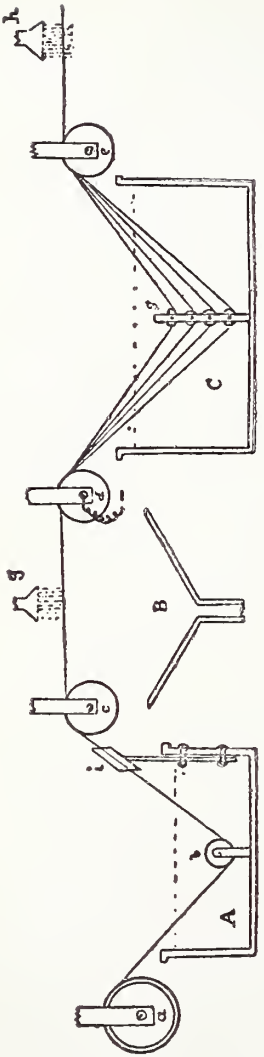


Fig. 54.

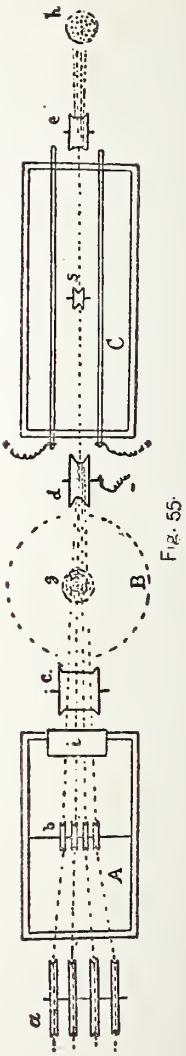


Fig. 55.

metallic zinc is formed upon the wire, when it is brought into the tin bath. The latter is prepared by suspending 2 parts of tin-salt in a

bag in a vessel containing a solution of 2 parts of tartaric acid in 100 of water. The tin-salt being dissolved, stir the fluid until the white precipitate formed is dissolved, and then add in small portions a solution of 3 parts of soda. In consequence of the development of carbonic acid vigorous effervescence takes place and a white precipitate separates. The fluid is now allowed to rest until clear, when it is drawn off, and the wire, which has been previously connected to zinc plates, is immersed in the tin-bath for 2 or 3 hours. The tin deposits as a dead-white coating capable of a high polish; the wire need only be passed once through the draw-iron in order to acquire a beautiful lustre and to make the coating of tin to adhere firmly. Small articles of iron may be readily tinned by previously providing them with a thin coat of copper. This is effected by first immersing the bright articles in a boiling solution of chloride of zinc, and, when they have acquired a coating of zinc, in a copper bath melted under a cover of borax. The articles being thinly coppered may, with the assistance of sal-ammoniac, be readily provided with a firmly-adhering deposit of melted tin.

To Harden Steel Piano Wire.—Heat the steel wire to a red heat, and then cool in the ordinary manner. Then immerse it in a metal bath composed of lead 40 parts, zinc 12, antimony 26, tin 21, and bismuth 1. The bath should be heated somewhat above its melting point, and the wire allowed to remain in it until it has acquired the temperature of the bath, which takes, of course, a longer time the thicker the wire is. When taken from the bath cold water is sprinkled or poured over the wire. The hardening and tempering above described are, as a rule, effected immediately *before* the last drawing, and only *after* the last drawing, when the wire is not required to be bright.

Coating which does not Oxidize Readily upon Steel and Iron Wire.—Villiers produces such a coating by immersing the wire in a weak acid solution, and after thoroughly washing, drying it at 176° F. The wire is then immersed in a fluid alloy of tin 90 parts, lead 9, and silver 1, rinsed in cold water and dried.

XVII.

MISCELLANEOUS.

Manufacture of Basic Open-hearth Steel.—In experiments made by J. H. Darby, four 12-ton and afterwards two 20-ton furnaces were used. Each furnace is provided with a separate chimney, ordinary butterfly reversing valves of ample size, and regenerator chambers of large capacity. The furnace proper is composed of two wrought-iron sides, supported by H iron buck-staves, well braced together at the top and bottom. The ends are left open; holes are cut in the plates for the three doors on the front side of the furnace, and another hole is made at the back for the tap-holes. The plates are also cut away, to allow air to circulate for cooling purposes under the furnace bottom and bridge plates. The silica blocks at each end of the furnace are built in the usual manner. The roof is level from block to block; the ends, however, are well inclined, to bring the flame down on the metal. On the iron plates for holding the dolomite hearth fire-bricks are placed, so that no part of the basic hearth when finished is more than 15 inches thick. As soon as all the brick-work is dry, hard-burnt dolomite, well ground and mixed with as little anhydrous tar as is needed to make it stick together when compressed, is rammed with hot irons until the desired shape of the hearth is built up; the tap-hole is made by a round piece of wood, which is left in and burnt out as the furnace heats up. The shrunk dolomite or basic material is brought up to the bottom of the doors and to an equal height all round. On it a layer of about 2 inches chrome ore, also ground fine and mixed with tar, is rammed to act as a neutral separator between the acid and the basic portions; chrome ore is also rammed in between the silica blocks and the basic hearth. The side walls and jambs are built on the chrome ore. The roof is then put on and the furnace heated up, at first with a coal fire. When the furnace is properly dried and heated the hearth will become very hard; the tap-hole should be cleaned out, and then filled with dry, ground, basic material for several inches. This should be well pushed up against a scraper held from the middle

door. Anthracite coal is then rammed in, and the outside of the tap-hole is covered with damp sand. The charge may now be introduced. Mr. Darby uses 80 per cent. of pig and 20 per cent. of scrap. Limestone is usually charged in sufficient quantity to make a basic slag from the first, scrap and pig follow. When sufficiently hot, additions of iron ore and limestone are made at intervals during about five hours. The first sample is taken, and from its appearance and fracture it is judged if sufficient ore has been added. If so, as much as possible of the unspent oxide is reduced in the slag by reacting on the remaining impurities, lime additions being from time to time made. The hammered sample rapidly improves. The edges, which were at first rough, become smooth and free from cracks; the surface of the sample is clean, and when the charge is ready it will bend over into four thicknesses without any indication of cracking. Ferro-manganese is then added, and the charge is *teamed*. Any kind of iron ore may be used in the steel furnaces, providing it contains a low percentage of silica. The 20-ton furnaces make from 180 to 200 tons of ingots per week, or 23.3 cwt. per hour, exclusive of Sundays. After experience in the manufacture of over 60,000 tons of basic, open-hearth steel, Mr. Darby has never seen red-short material in the usual soft quality. An average analysis of the soft steel is as follows:

$$C = .12 \text{ p. c.}, \quad P = .03, \quad S = .018, \quad Si = \text{nil}, \quad Mn = .400.$$

This steel gives about 24.5 tons tensile strain per square inch and 15 tons elastic limit, with an elongation of 31 to 33 per cent. in 8 inches.

The Carlsson-Bessemer Process.—The Carlsson modification of the Bessemer process is employed in Sweden in the treatment of a charcoal pig-iron containing about 1.5 per cent. of silicon, 0.1 to 0.15 of manganese, 3.9 of graphite and 0.1 of combined carbon. The slag produced in the production of this pig-iron approximates more closely to a trisilicate than a bisilicate, alumina being considered as a base. After the pig-iron has been charged into the

converter, it is blown for about 5 or 6 minutes, until the blue flame appears that marks the commencement of the combustion of the carbon. The blow is then stopped, and a definite proportion of the charge, varying with the quality of the metal it is desired to produce, is poured into a ladle of peculiar construction, so arranged as to show the weight of the metal charged into it, the slag being carefully removed. This portion of the charge usually contains 4.15 per cent. of carbon, 0.05 of silicon and 0.07 of manganese. The remaining portion of the metal in the converter is then blown until most of the carbon has been eliminated and the bath converted into malleable iron. The portion of the metal previously removed, together with any necessary additions required for special purposes, is then added to the bath. When the reaction that ensues is ended the metal is ready for pouring. Before this addition is made, the bath usually consists of metal containing a trace of silicon, 0.03 per cent. of manganese, 0.05 per cent. of carbon and, as a maximum, 0.02 of sulphur. As this metal is usually red-short, some rich manganese iron is added before the addition of the second portion of the metal from the ladle. The percentage of silicon in the final product is usually about one-tenth of that of the carbon, so that steel containing 0.2 of carbon would also contain 0.02 of silicon.

Malleable Cast-iron.—The custom among most malleable iron makers is to use such irons only as are quite free from phosphorus and sulphur, for the reason that the process in use is designed especially to eliminate carbon, and after they have driven that out they have no desire to leave anything remaining which will make the metal brittle. By the use and mixture of certain brands of iron they have the means of converting their product into almost pure wrought-iron.

The melting is now done, on the large scale, in reverberating furnaces, and the iron is purified, to a certain extent, while in a molten condition by directing into the heating chamber a current of atmospheric air which mixes with the products of combustion. In its essential principles the method has a resemblance to Berard's process of steel-making—the gaseous currents of air or of the fur-

nace may be used, as occasion requires, alternately, but the tuyeres are not, like his, provided with apparatus for adjustment. The process of removing impurities from the metal must not be carried so far as to detract from its fluidity at the temperature at which it is to be poured. These facts control the operation; the purer the metal is the higher is its melting point, and whatever impurities are allowed to remain must be such as may either be removed by subsequent operations or such as may be allowed to exist in the finished product. The useful function of the impurities is to lower the melting point in the scale of temperature. Small test pieces, of a finger's length, are cast from time to time until the right point is reached, as determined by the appearance of their fracture. The metal is then ready to be poured into the moulds, and as these will hold no large amount the pouring is generally done from hand ladles. After the cast pieces are removed from the sand and have the risers, runners and sprues knocked from them, they are rattled in tumbling barrels to remove the adhering sand and scale and to expose the naked surface of the material to the ready access of the chemical agents of decarbonization.

The cast-iron pieces, hard and brittle, are now ready for the process which will alter them in their whole nature without subjecting them to any physical force. The process is one of dissociation of the compound cast-iron, which is carburet of iron; the carbon has purposely been made to appear in its combined form and is not visible as graphite; the iron, when broken, exhibits a fine white appearance of the fractured surface, with a suggested indication of lines radiating from the centre.

The pieces are packed in cast-iron boxes with the rust or oxide of iron. These boxes are round or square, according to the shape of the work. If round, they are perhaps 2 feet in diameter, and, if rectangular, they may be 2 feet long, 1½ feet wide and 1 foot high. When these are filled rims of the same size are placed on them, increasing the height another foot, and when these are filled another rim, and still another is added, until the box is 4 feet in depth, packed full of castings and oxidizing metal. This material may be wrought-iron turning-chips which have been rusted by be-

ing spread upon a hot floor, where they were sprinkled with a solution of sal-ammoniac.

After the boxes are packed they are placed in a double row in brick chambers or ovens, which are large enough to contain twenty. The aperture through which they were carried in is now walled up, and fire is admitted to the chamber from a furnace at one side. The flames fill the chamber and pass out to the flue on the opposite side. The firing is continued for 3 days or longer, if required, and the work having been brought to a red heat perhaps the first day, stands for the remaining time immersed in this red-hot bath of flame. When the time for firing the furnaces has expired they are suffered to cool off slowly, and in a day and a half the boxes are removed from the ovens and dumped on the large cast-iron floor. This floor is a necessary part of the plant. When it is used for oxidizing the turning-chips it is heated by the hot air from the furnaces, which may be caused to pass underneath it on their way to the chimney. It is not heated when the contents of the boxes are emptied upon it, and when these are cool enough to handle the iron turnings which have become caked upon them quite strongly are knocked off and the pieces are carried to the tumbling barrels, where they are rattled until bright.

The cast-iron articles subjected to the above process have a malleable skin only; the depth of this is determined by the thoroughness of the process, and the core or body of the material beneath this is still brittle. For this reason screws made from it having threads cut through the skin are deficient in strength. The skin is as refractory to melt as wrought-iron, but if this skin is broken and the piece heated to a white heat the inside will either run out of the rupture in a fluid state or, if it does not flux, it will shake out like sand. In this way articles of intricate shapes may be made light of weight by pouring out the fluid interior and leaving the harder outer shell.

The chemical change in the iron which the annealing produces is so great that the boxes used to anneal in, and which are so long exposed to heat, will last four or five times as long if cast from malleable scrap than they will if cast from pig-iron. For melting

pots for the more fusible metals and alloys, such as lead, tin or babbitt, this metal is far preferable to common iron. It is also of great value for making cast-iron gas retorts, which are still in use to some extent, though generally superseded by fire-brick in gas-works. It is excellent for use in making any articles that are to be exposed to continuous heat, as pipe, in connection with furnaces.

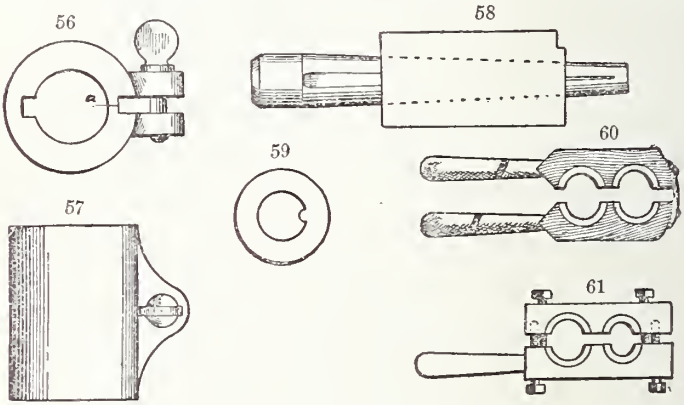
Lead Lapping.—This process consists of grinding work in a lathe by means of emery powder, oil being mixed with the emery to hold it in place and render its application possible. A lap is a mandril used to grind holes which are not quite true, or are too small, or have been hardened and cannot be cut by a tool. A lap may be a piece of copper rod, or of iron, with a tin or lead coat around it. The diameter of a lap should be turned to an easy fit, at both ends in the hole, and a trifle larger in the middle, so that the hole which it is intended to grind will fit tightly on the mandril, the lathe being three times the length of the former.

Put the lap in the lathe and through the hole to be ground, run the lathe at high speed, and apply oil and emery, moving the work back and forth until it will pass easily over the large part of the lap; then stop the lathe and hack the lathe with a cold-chisel, put on more oil and emery, and grind as before. Care should be taken that the work is rotated, in order that all sides of the hole grind evenly. For holes to be made true, smooth and parallel, the work is bored as well as possible, then set upon a true surface like a planer table, and the lap applied. The mandril should be very long and tapered, and for hard lapping the extreme end of the mandril should be fitted to a bearing, bolted to the planer table, and the office of this bearing is to prevent all erratic movements of the mandril while grinding. The process is the same as for hard lapping, except the work is moved by power. Care must be taken that the lap does not become dry during the process. If it does there is apt to be heating and destruction of the lap-surface, even if no harm comes to the object being finished.

Lead lapping is resorted to when great accuracy of surface is desired, as well as high polish, and where a finish by filing and an

application of emery paper would not do, although the method is sufficient for rough work and small journal bearings.

Figs. 56 and 57 show a form of lap. It is a cast-iron cylinder, or sleeve, split nearly in two, as shown, and fitted with lugs and a thumb-screw to admit of changing the size of the sleeve. It will be noticed that the cast-iron sleeve comes entirely together at *a*, and the size of the object to be ground is determined by this stop. If the lap becomes too much worn, a little metal may be filed from the surface which comes in contact. The interior of the cylinder is



brushed with lead and charged with a flux of emery and oil, the thumb-screw is loosened, and the lap applied to the object to be ground, when it is running in the lathe at a speed of 300 lineal feet per minute.

For some work the cast-iron cylinder may be made with a hinge opposite the thumb-screw, giving ready access to the interior of the lap.

Fig. 59 is an internal lap. It is simply a piece of lead, cast in the taper arbor, which is fluted to prevent the lead from revolving upon it. The lead is turned to size and charged with emery and oil. The size is maintained by driving the taper arbor further through the lead, which, being forced out by the round arbor, ex-

pands in every direction, and thus keeps its shape. Fig. 58 shows an end view of the arbor and the lead tap upon it.

A cheap lap for coarse work is shown at Fig. 60. It consists of two pieces of pine wood, cut out as shown, to receive the shafts, and a leather hinge to connect the parts. To polish a shaft, open the clamp, daub oil and emery in the notches and close the lap upon the work. Fig. 61 shows a more accurate form of the variety of lap. The pieces are made of cast-iron and brushed with lead, then reamed, as already described. The set-screws shown on top of this lap determine the size of the hole to fit the work, and the bottom screws clamp the lap firmly against the set-screws. (James. F. Hobart.)

*Sawing Iron and Steel.**—In a machine shop there is a constant demand for means to cut off or to nick pieces of iron and steel that cannot readily be put into the lathe on centres. The nicking saw is the usual method employed, the saw being driven on centre by a dog, as a shaft would be termed, and the work to be sawed fed to it by the cross feed or other means. To make these nicking saws and to properly temper them tries the patience of the mechanic that does not understand the "know-how." It is simple. First, do not turn or face up a nicking saw. Cut it out of sheet cast-steel without a particle of forging, selecting the steel of the proper thickness. During all the process of making do not disturb the "skin" of the steel formed by the rolls under which it was made, either by filing, smithing or polishing. Cut the disk out with a cold-chisel and file it to circle; file the teeth like those of the straight iron saw—those of the common "buck-saw" for wood sawyers are a pattern—and make no set on them. Iron saws require to make no kerf. The teeth need not project on either side. Of course, the saws must be drilled for a mandril, which should be of steel, before they are toothed, being turned true on the mandril, to which they should be secured by check-pin and nut. It is economy to make a dozen or even more at a time. Drill the mandril hole and the notch in the hole for the check-pin, or "steady-pin" as some call it, turn them as a whole, and cut the teeth all

* Jesse H. Lord, in *Manufacturer's Gazette.*

together in a slabber or milling machine. All this without smithing or facing up in the lathe, preserving the steel-face intact.

The sizes of these saws for ordinary shop use are confined, for efficient practice, to a diameter of 3 inches, or at most 3½ inches, ranging downward, until for some work, diameters of 1 inch, cutting not more than ¼ inch under the mandril are necessary.

To temper these saws is the great trouble with many workmen. The saws vary in thickness from ⅛-inch to $\frac{1}{16}$-inch and in diameter from 3 inches to 1½ inches, sometimes exceeding the higher size and sometimes being less than the lower size mentioned.

Each saw must be separately hardened and tempered. To do this properly the saw should be put upon a rod, with nut to hold it in place, and heated over or in a charcoal fire, or over one of well-coked sea coal, to a good red heat and plunged, slantwise, in cold water, and moved about until cool. To temper the saw, smear it when dry with animal oil—not kerosene, but sperm or lard oil—and hold it over the fire until the oil takes fire and flashes in flame over the surface of the saw. Let the oil burn a moment and then quench it again. If the saw is sprung it may be straightened by the hammer on the anvil, by fair blows, without danger of breaking. Some prefer to draw the temper by heating a bar of iron of about the size of the centre hole in the saw, and putting the saw on it so that the heat will work gradually out to the circumference, when the temper will be determined by color, usually a straw. If, however, color drawing is preferred, a better way is to draw in a pan of heated sand, clean and without salt, as beach sand gives off fumes that discolor the steel and mislead the eye. The oil test will be found the best.

The speed at which these saws should be run depends somewhat on the material to be cut, brass and other soft metals allowing a quicker speed than iron and soft steel. About 100 revolutions per minute will do for three-inch saws, giving about 75 feet of circumferential motion; but as the nicking saw is only a thin mill, the speed of the mill in a milling machine is a good guide.

It may be necessary, sometimes, to cut off a piece of hardened steel. This may be done by an untoothed disk of muntz metal, or

of hard-rolled sheet brass, fed with quartz sand and water, or by kerosene oil and emery. In this case it is the sand or emery that does the cutting, the disk's edge merely presenting the abrading material to the work. The sand and water, or the emery and oil are handily fed through a common funnel suspended over the work, the amount being regulated by a stick placed in the funnel spout.

Utilization of Red-brass Turnings.—Turnings from red-brass works are frequently sold for a low price, even by establishments having facilities for casting in crucibles, because they are apparently not fit for casting. These turnings can, however, be profitably utilized for new castings as well as an addition to other charges. The process is as follows: The turnings are melted by themselves and during the melting process mixed with manganic oxide in the proportion of 5 parts by weight of manganese to 100 of turnings. In charging for melting, it is advisable to cover the bottom of the graphite crucible 0.39-inch deep with manganic oxide; upon this is placed a layer of turnings about 1.18 inches deep, and so on until the crucible is full. During melting the impurities contained in the turnings settle on the surface and can be readily removed with a graphite ladle. The melt is best cast in buttons (square pieces). When cool each button is cut, in order to determine the qualities of the metal by the fractured surfaces. The metal melted in this manner shows a reddish, nearly coppery fracture, and is very tenacious and dense. An addition of manganic oxide, not exceeding, however, 2½ per cent., to new material for melting is also recommended. With this method the crucible should not be covered with tallow, fat, pitch, etc. Boxes for rapidly-running parts of machines showed great durability, being but little worn after years of use.

Recovery of Copper.—In works where great quantities of copper are operated upon, it is advantageous to recover the metal dissolved in the cleansing baths, which are allowed by the majority of gilders, silver electro-platers and galvanoplastic operators to go to waste with the rinsing water. The recovery of such copper is an easy and inexpensive process. All the liquids holding copper

are collected in a large cask filled with wrought- or cast-iron scraps. By the contact of the copper solution with the iron a chemical reaction immediately takes place, by which the iron is substituted for the copper to make a soluble salt, while the copper falls to the bottom of the cask as a brown powder. The cask should be sufficiently large to hold all the liquids employed in a day's work. The liquids are decanted every morning. The old iron scrap is generally suspended in a willow basket near the top of the liquid, and, by occasionally moving it about in the liquid, the metallic powder of copper alone falls to the bottom of the cask.

The same method is employed for recovering the copper from old cleansing acids or from spent galvanoplastic baths. The copper thus obtained is quite pure, and, by calcining it in contact with the air, a black oxide of copper is obtained, which is serviceable for enriching and neutralizing galvanoplastic baths too strongly acidified.

Recovery of Gold from Gold Baths, etc.—To recover the gold from old cyanide gilding baths, evaporate the baths to dryness, mix the residue with litharge and fuse the mixture. The gold is contained in the lead button thus obtained. The latter is then dissolved in nitric acid, whereby the gold remains behind in the form of insoluble spangles. These spangles are filtered off and dissolved in aqua regia.

The following method is used for the recovery of the gold by the *wet process:* The bath containing gold, silver and copper is acidulated with hydrochloric acid, which causes a disengagement of hydrocyanic acid. This gas is extremely poisonous, for which reason the operation should be carried on in the open air, or where there is a good draft or ventilation to carry off the fumes. A precipitate consisting of the cyanides of gold and copper, and chloride of silver, is formed. This is well washed and boiled in aqua regia, which dissolves the gold and copper as chlorides, leaving the chloride of silver behind. The solution containing the gold and copper is evaporated nearly to dryness, in order to remove the excess of acid, the residue is dissolved in a small quantity of water, and the gold precipitated therefrom as a brown metallic powder,

by the addition of sulphate of iron (copperas). The copper remains in solution.

Recovery of Gold and Silver from Sweepings and other Refuse from the Manufacture of Gold-ware, etc.—Collect the sweepings, dry them, if necessary, and heat them in a Hessian crucible, in order to destroy all the organic substances. Triturate the glowed mass in a porcelain dish or enamelled kettle with water, and treat it with an excess of hydrochloric acid to dissolve any alkalies or calcium carbonate present. The portion remaining undissolved contains gold, silver, copper, sand, clay, ferric oxide, etc. To recover the silver from it wash it thoroughly with distilled water and boil it in pure nitric acid, which absorbs the silver. The residue is again thoroughly washed, and from the combined fluids the silver is precipitated as chloride of silver by common salt, or, still better, by hydrochloric acid. The residue remaining undissolved after the treatment with hydrochloric acid is heated with aqua regia and the gold precipitated by the addition of sulphate of iron (copperas). Sometimes it may pay to treat the residue remaining undissolved in aqua regia with ammonia in order to extract the .chloride of silver, the formation of which under the given conditions can scarcely be prevented. An experiment with a small portion will show whether such treatment is advisable or not.

Ungilding.—Gilded articles of *iron* and *steel* are best ungilded by treating them as the anode in a solution of from 2 to 2¾ ozs. of 98 per cent. potassium cyanide in 1 quart of water, and suspending a copper plate greased with oil or tallow as the cathode. Gilded *silver-ware* is readily ungilded by heating it to glowing and then immersing it in dilute sulphuric acid, whereby the layer of gold cracks off, the glowing and immersing in dilute sulphuric acid being repeated until all the gold is removed. Before glowing and immersing in dilute sulphuric acid the articles may first be provided with a coating of a paste of sal-ammoniac, flowers of sulphur, borax and potassium nitrate, which is allowed to dry. On the bottom of the vessel containing the dilute sulphuric acid the gold will be found in the form of laminæ and scales. These

are boiled with pure sulphuric acid, washed, and finally dissolved in aqua regia and made into chloride of gold or fulminating gold.

To ungild articles of *silver*, *copper* or *German silver*, which will not bear glowing, the solution of the gold may be effected in a mixture of 1 lb. of fuming sulphuric acid, 2.64 ozs. of concentrated hydrochloric acid and 1.3 ozs. of nitric acid of 40° Bé. Dip the articles in this warm acid mixture, and observe the progressive action of the mixture by frequently removing the articles from it. The articles to be treated must be perfectly dry before dipping them in the mixture, and care must be had to preserve the latter from dilution with water in order to prevent the acids from acting upon the base-metals.

Utilization of Nickel Waste.—For the utilization of waste from rolled and cast-nickel anodes and of the nickel sand gradually collecting upon the bottom of the vats, the following method is recommended: Wash the waste repeatedly in clean hot water, and then boil in dilute sulphuric acid (1 part acid to 4 water) until water poured upon the waste is no longer clouded by it. Then pour off the liquid and treat the waste or sand with concentrated nitric acid. This must be done very carefully, and a large porcelain vessel should be used to prevent the solution from running over. When the solution is sufficiently concentrated, so that it contains little free acid, it should be filtered and slowly evaporated to dryness over the water bath. The product is nickel nitrate. The nickel nitrate thus obtained is dissolved in hot distilled water, and the solution precipitated with caustic soda carefully and gradually added. The precipitate of hydrated nickel oxide is then carefully filtered and washed, then treated with dilute sulphuric acid with the aid of heat until solution has taken place. The solution is concentrated by evaporation and an excess of concentrated solution of ammonium sulphate is added. The precipitate is the double sulphate of nickel and ammonium, or Adams' nickel-plating salt, which is commonly used for nickel-plating.

To Recover Nickel from Old Solutions.—Urquhart proposes the following plan: Make a saturated solution of ammonium sulphate

in warm water and add to it the old nickel-plating solution, with constant stirring, and, after the lapse of a few minutes, a granular precipitate of the double sulphate of nickel will begin to separate. The addition of ammonium sulphate should be from time to time continued, until the liquid is colorless. The precipitated salt is very pure, and may be used directly in making a new bath.

Recovery of Silver from Old Cyanide Plating Solutions, etc.—The baths may be evaporated to dryness, the residue mixed with a small quantity of calcined soda and potassium cyanide and fused in a crucible, whereby metallic silver is formed, which, when the heat is sufficiently increased, will be found as a button upon the bottom of the crucible; or if it is not desirable to heat to the melting point of silver, the fritted mass is dissolved in hot water, and the solution containing the soda and cyanide quickly filtered off from the metallic silver. The evaporation of large quantities of fluid is, to be sure, inconvenient, and requires considerable time, but the reducing process above described is without doubt the most simple and least injurious.

According to the *wet method* the bath is strongly acidulated with hydrochloric acid, observing the precaution to provide for the effectual carrying off of the hydrocyanic acid liberated as given under gold. Remove the precipitated chloride of silver and cyanide of copper by filtration, and after thorough washing, transfer it to a porcelain dish and treat it, with the aid of heat, with hot hydrochloric acid, which will dissolve the cyanide of copper. The resulting chloride of silver is then reduced to the metallic state by mixing it with four times its weight of crystallized carbonate of sodium and half its weight of pulverized charcoal. The whole is made into a homogeneous paste, which is thoroughly dried, and then introduced into a strongly heated crucible. When all the material has been introduced the heat is raised to promote complete fusion and to facilitate the collection of the separate globules of silver into a single button at the bottom of the crucible, where it will be found after cooling.

If granulated silver is wanted, pour the metal in a thin stream, and from a certain height, into a large volume of water.

Desilvering.—According to the nature of the base-metal different methods have to be employed for desilvering. Silvered *iron articles* are treated as anode in a potassium cyanide solution in water (1:20), the iron not being brought into solution by potassium cyanide; as cathode suspend in the solution a few silver anodes or a copper-sheet rubbed with an oily rag. The silver precipitates upon the copper-sheet, but does not adhere to it. Articles, the basis of which is *copper*, are best desilvered by immersion in a mixture of equal parts of anhydrous (fuming) sulphuric acid and nitric acid of 40° Bé. This mixture makes the copper passive, it not being attacked, while the silver is dissolved. Care must, however, be had not to introduce any water into the acids, nor to let them stand without being hermetically closed, since by absorbing water from the air they become dilute, and may then exert a dissolving effect upon the copper. The fuming hydrochloric acid may also be heated and 150 parts of crystallized nitrate of soda be added instead of the nitric acid. In this hot acid desilvering proceeds more quickly than in the cold acid mixture, but the latter acts more uniformly. Desilvering is complete when the articles, on being pickled, show no stains.

Recovery of Platinum from Platinum Solutions.—From not too large baths precipitation of the platinum with sulphuretted hydrogen is the most suitable method, and preferable to evaporating and reducing the metal from the residue. The process is as follows: Acidulate the platinum solution with hydrochloric acid, and, after warming it, conduct sulphuretted hydrogen into it. The metal (together with any copper present) precipitates as sulphide of platinum. The precipitate is filtered off, dried and glowed in the air, whereby metallic platinum remains behind. From larger baths the platinum may be precipitated by suspending bright sheets of iron in the acidulated bath. In both cases the precipitated platinum is treated with dilute nitric acid in order to dissolve any copper present. After filtering off and washing the pure platinum it is dissolved in aqua regia; the solution is then evaporated to dryness in the water bath, and the chloride of platinum thus obtained may be used in making a new bath.

Recovery of Tin from Tin-plate Waste.—The waste is treated with dilute chlorine at a temperature above the boiling point of chloride of tin, so that the latter immediately after its formation is carried away in the form of vapor, as, if it remains in the form of a fluid in contact with the residues, it gives rise to the formation of chloride of iron, chloride of tin being reduced. The vapors of chloride of tin are precipitated by steam or by contact with moist surfaces in roomy condensing chambers, or are absorbed by chloride of tin solution of medium concentration.

Another method is as follows: Bring the waste into contact with sulphur in a boiling-hot solution of sodium sulphide, whereby the iron is completely freed from tin. The waste thus freed from tin is thoroughly washed and dried, heated to a welding heat in tubes of rolled-iron, taken out and hammered into rod-iron. The solution of sodium sulphide holding the tin is evaporated, the residue calcined in a reverberatory furnace and the calcined mass reduced to tin, at a raised heat, by means of a mixture of small coal, charcoal and calcined soda or burnt lime.

To Separate Lead from Zinc.—Melt the alloy. The specifically heavier lead collects in the lower portion of the crucible, while the lighter zinc stands above it and can be poured off.

How Japanese Swords are Made.—In forging the metal is never heated without being carefully coated with loam spread all over it as a thin wash and sprinkled with straw ashes. The metal, too, is kept perfectly clean, and never touched by the hand, as the least sweat will hinder the perfectly uniform welding of the parts together and leave a flaw visible in the sword. A steel plate with an iron rod welded to it as a handle, and with several pieces of steel placed upon it, is heated in the fire, and is hammered out on the anvil to a shape about 6 or 8 inches long by 1¼ inches wide and ¼ or ¾ inch thick. The steel bar so forged is doubled over, heated again and hammered out into about the same dimensions as before; doubled over again, reheated and hammered until it has been refolded fifteen times. Then its handle is cut off, and in like manner three such bars are made and the four bars welded into a somewhat longer bar, and thus again folded and hammered out to about

the same dimensions. The resulting bar is made up of a vast number of layers intimately welded together. The first doubling gives 2, the second 4, and so on up to the fifteenth, which gives 32,768, and the four small bars together consist of 131,072 layers, and after 15 additional foldings there must be 4,194,304 layers. In consequence, the polished sword has fine lines like the grain of wood. They are called the sword's *hada* (skin), and are distinguished by names according to their form. The steel bar is now hammered out to the length of the required blade, and after various manipulations is given its shape, apparently without measurements or patterns. When iron is used along with the steel there are several ways of combining the small bars to make the large one, the smiths of different provinces using different methods. In hardening, the blade is covered with a coating of loam, which is carefully removed along the edge, and is then heated in a vigorous fire of pine charcoal. Afterwards it is cooled by dipping in lukewarm water. The blade is then carefully cleaned and examined for blemishes. A smith careful of his reputation rejects all imperfect blades and uses the material for other purposes. Next the smith cuts the groove, if any, with a steel graving tool. These grooves lighten the sword, and are called vulgarly *chi-nagashi* (blood chains). The smith then drills the hole in the tong for the bamboo or metallic peg that holds the handle on.

Many smiths adorn their blades with engravings, especially with representations of dragons, gods, and flower sprigs.

The final grinding and polishing is a trade quite distinct from the smith's. The grinder holds the sword horizontally, and rubs it back and forth on a small whetstone well wet with water, moving by degrees along the whole length of the blade. Finally the blade is polished with a polishing stone and a stone powder as fine as flour, or with the finest powdered steel forge cinders until the polish is perfect.

The blade may now be mounted with a hilt, and, if moderately long, with a guard, with a ferrule and a scabbard. The hilt is made of wood often covered with shark's skin, the rougher the better. Over the shark's skin silk cord is often found crosswise in several

styles. Between the shark's skin and the cord there is often a metallic ornament. The guard is only put on the larger swords, and is preferably made of steel or the hardest wrought-iron. It is sometimes a work of fine art, and then often has the maker's name engraved upon the concealed part of it.

To Make Knives from Old Files.—First draw the temper by heating the file to a cherry-red, then place it in ashes, and 5 inches under the forge, and leave it there until cool. Now grind out the file marks and next comes the drawing. Make the heat no higher than a bright cherry heat, and use a good smooth-faced hammer. The file is then drawn a little thicker than the back of the blade is to be, and the blade is then bent, the edge being on the inside. The blade is then drawn to an edge, the drawing on the inner curve having the effect of straightening it. When it has been drawn to an even and nice color and straightened, three holes are drilled in it so that the handle can be fastened on it, and it is shaped with a file. It is necessary to avoid getting the edge too thin, or else there will be trouble in tempering. In tempering use soft and somewhat warm water. Seize the handle ends with a pair of tongs, hold the blade, with the back down, over a clear, well-charred fire, and heat evenly to the first hole until the blade is red, and then plunge it endwise into the water. This should leave the blade so that when tried with a file the file will take hold, just a little. If this test shows that the blade is too hard, dip it in linseed oil, hold it over a slow, clear fire until the oil ignites, and then dip into the water again. This will toughen it, and cause it to hold its edge better. The grinding should be done on a good even-faced stone.

Manufacture of Metal Pipes.—The following process, the invention of F. Madeley, is patented in England: A piece of soft steel is in a suitable manner bent to a pipe so that both edges lie close together It is then polished and coated with copper in a suitable cyanide solution. For a layer of copper of special thickness it is further treated in a solution of cupric sulphate. The pipe is then further coated with brass in a suitable cyanide solution and finally polished. In this manner pipes with a metallic coating are obtained without the necessity of soldering or welding.

Improvement in the Treatment of Steel.—C. Jones, of Derby, England, has patented the following process: Steel scraps (railway carriage and other carriage springs), after being cleaned by immersion in dilute sulphuric acid and subsequent washing in boiling water, are first dipped into oil or grease and then into soot. The scraps are then packed with powdered gas coke into a metal box and heated in a furnace for 30 hours or more, at about 1400° F., then withdrawn and allowed to cool slowly. The scrap may then be melted into blocks or ingots, which can be rolled, welded, hammered or otherwise treated in the usual way.

Ink for Writing on Tin.—Dissolve 1 part of copper in 10 of nitric acid, and add to the solution 10 of water. Cleanse the tin with dry whiting and write with a quill.

Ink for Writing on Zinc.—Cleanse the surface of the zinc by rubbing with a sponge dipped in dilute hydrochloric acid and fine sand. Next dissolve 1 oz. 4 drachms each of crystallized verdigris and sal-ammoniac in 1 pint of warm water, filter the solution after cooling, and preserve it in well-closed bottles. Pieces of zinc written on with this preparation are allowed to lie in water a few hours. They are then dried and used without being varnished. The writing may be executed with a steel pen or a quill, the first being, however, strongly attacked by the fluid. In case the zinc appears greasy and the writing runs together, cleanse the surface with a rag dipped in chalk. This ink is very suitable for writing labels.

Insulating Coverings for Steam-pipes, etc.—Felt, cork, waste, mineral wool or asbestos pulp, either made into suitable forms and atttached to the pipe, or filled into a casting surrounding the pipe, and with or without an air space about the pipe, are much used for the above purpose. A mass highly recommended is prepared as follows: 100 parts by weight of finely ground limestone, 350 of finely ground coal, 250 of pulverized clay, 300 of fine ashes from boiler-flues are thoroughly mixed with 600 of water and 10 of sulphuric acid of 50° Bé, and after adding 15 of hair (hogs' bristles, cow hair or calf hair) the whole is made as homogeneous as possible. The article to be covered should, if possible, be previously heated.

The mass is then gradually applied in separate layers, each about ½-inch thick, until a thickness of 1½ to 1¾ inches is attained. The whole may finally be painted any color desired.

Another Insulating Material for Steam-pipes is prepared as follows: Boil 1 lb. each of rice flour, rye flour, cows' hair and treacle with 150 quarts of water, and gradually and with constant stirring add 80 lbs. of infusorial earth. Apply the mass in several layers to the lukewarm pipes, so that finally a layer somewhat more than ½-inch thick is formed.

Insulating Mass for Steam-boilers, etc.—Waste of cork, asbestos, gypsum and cement, all finely ground, are shortly before use made with water into a paste of the consistency of mortar. The resulting mass is applied with a trowel to the objects to be insulated. It answers the purpose far better than masses containing hair, glue, treacle, etc., as it is not subject to putrefaction or fermentation, nor destroyed by heat. It being a very poor conductor of heat the highest useful effect can be attained; it adheres well and is very durable.

Insulating Material for Electrical Conduits.—Mix 66 parts of fine glass or quartz powder and 34 of finely pulverized vegetable or mineral resin. Add to the mixture 26 parts of paraffine, beeswax or spermaceti, and 3 parts of boiled or crude linseed oil. The proportions of mixture vary according to circumstances. If the mass is to be exposed to the sun the admixture of wax must be small, while the reverse is the case if the mass is to be used for telegraph lines under ground.

Flexible Insulating Mass for Electrical Conduits.—Mineral wax (paraffine, ozokerite), 1 part; wood tar, 29; shellac, 32; and asbestos, flax or cotton, 32, are mixed in a boiler at between 92° and 212° F., and constantly stirred. For a harder mass take less wood tar. For the production of a specially hard mass, the wax may be omitted and about 24 parts of ground slate, infusorial earth or clay free from iron added, and the quantity of asbestos, etc., decreased.

Gold-beating.—The rough gold is put into a stone crucible, melted, and poured into a mould, which gives it the right width

for rolling. One hundred dollars' worth of gold is generally moulded at a time, the weight being about 5 ounces. It is then run through the rollers, the pressure of which is so great that the little bar of gold that is 1 inch thick in width and about 3 inches in length, after being run through several times, becomes a strip about 14 yards in length and about the thickness of a hair. The strip is then cut into 1 inch squares. These squares are put into what is called a *cutch*. This cutch is composed of 180 skins 3½ inches square. The material that these skins are made of is an invention of French origin, and is kept secret. Formerly vellum was used. A gold square is placed between each skin, one directly over the other, until the cutch is filled. Two parchment bands are put over them in opposite directions to keep them from shifting. The cutch is then beaten for 15 or 20 minutes with a 16-pound hammer. The gold is then taken out of the skins, quartered by a skewer, and put into what is called the *shoder*. The number of skins in a shoder is 680. These skins come from what is called the bung-gut of an ox, one animal furnishing but two skins. The shoder skins are four inches square. The gold squares are put between the skins in the same manner as in the cutch. They are then beaten for 1½ hours with a 10 lb. hammer, taken out, and again quartered with a piece of reed. They are then put into the mould, one over the other as before, until the 900 skins which the mould contains are filled. This is beaten with a hammer weighing 7 lbs. for 3 or 4 hours. The leaf is then ready to be trimmed and booked. Before the beating process the skins are heated and primed to prevent the leaf from sticking. Heated presses are used to take the moisture from the skins. Each skin is rubbed with a hare's foot, with plaster of Paris on both sides, before beating. Each one of the first squares of gold beaten out makes 25 leaves, or one book. The trimming of the leaves before they are put into books is done by a sled-shaped machine called a wagon. The trimming and booking are mostly done by girls. The trimmings that are left from the leaves are scraped together and melted over. A little salt added makes it thoroughly clean. The granite block that the beating is done on is about 3 feet in height, the top

surface being ground down perfectly smooth, so as to prevent the blows of the hammer from cutting the under side of the mould.

Lining for Furnaces.—The composition used for lining furnaces consists of ganister, or a similar highly silicious mass, and lime in the proportion of about 90 parts of ganister to 10 of lime. The limestone is burned and slaked, and after 12 hours added to the ganister. Sufficient water for the requisite consistence is then added and the whole thoroughly mixed. The furnace is then lined with the mass and the latter dried by moderate firing.

Matrix Mass for the Reproduction of Medals, Coins, etc.—Under the name "isolit" a mass is brought into commerce which is recommended as being especially suitable for matrices to be used in galvano-plasty. It consists of yellow ceresin (purified ozokerite), with 6 or 7 per cent. of petroleum and 4 or 5 per cent. of sulphur.

Oil of Mustard as a Lubricator.—For preventing the welding together of iron surfaces upon which much and rapid friction is exercised, such as turbine wheels, etc., ordinary oil of mustard, mixed with small quantities of petroleum, fish oil, or other similar fatty substances has been found to answer the purpose in every respect, and to overcome all the difficulties heretofore experienced with machinery where excessive friction disturbs the physical quality of the metal used.

Spinning of Metals.—Spinning in the lathe is preferably employed for shaping articles which are difficult to press or draw. The principle of spinning consists in forcing by the continuous pressure of a tool of a simple shape a sheet of metal into a revolving pattern (chuck) or raising it over the chuck. In the first case the inner surface of the chuck must correspond to the outer contours of the article to be produced, whilst in the latter the chuck actually forms the pattern of the work.

Fig. 62 shows both styles in cross-section and also the manner of securing the chucks in the lathe. *F F* are the chucks; they are made of hard wood, generally white beach. Upon metallic chucks the sheet-metal would very quickly spin hard; the wooden chucks, however, are frequently covered with sheet-brass. The chucks

must be turned very smooth, and are provided on one side with a female screw, by means of which they are secured to the front end of the mandril *S*, which is provided with a worm. This end is also furnished with a female screw, in which fits the so-called binding screw *D*. The latter consists of a steel rod, provided on one end with a worm about 1½ inches long and on the other with a disk and handle. The length of the binding screw generally corresponds to the longest article to be turned; for shorter articles various orbicular pieces *V* are inserted between the chuck and the disk of the binding screw. With the use of the binding screw the

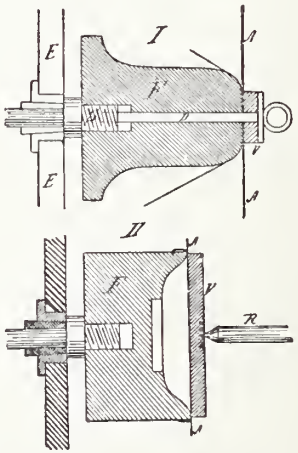


Fig. 62.

chuck as well as the sheet-metal to be spun must be provided with an aperture for the binding screw to pass through. The chuck and disk of sheet-metal before the commencement of spinning are shown in *I*, Fig. 62.

The spinning is done with tools of various shapes resembling burnishers; they have either flat, flat-round, club-shaped or hook-like faces. Some of the shapes are shown in Fig. 63. The tools should always be kept dull and smooth; sharp-edged or rough tools must never be used. A strong steel pin is inserted in the

projection of the lathe, against which the tool is pressed during spinning. The tool is held in the right hand and pressed in slow strokes from the centre towards the periphery, progressing in a horizontal direction from right to left, whilst the plate of sheet-metal is made to revolve by the mandril; the plate is thereby forced to gradually fit itself to the chuck. What shape of tool is most suitable for each kind of work has to be learned by experience, it being impossible to give special instructions in regard to this. It need only be remarked that at first flat-round tools are always used even in spinning sharp edges; flat tools are only employed finally.

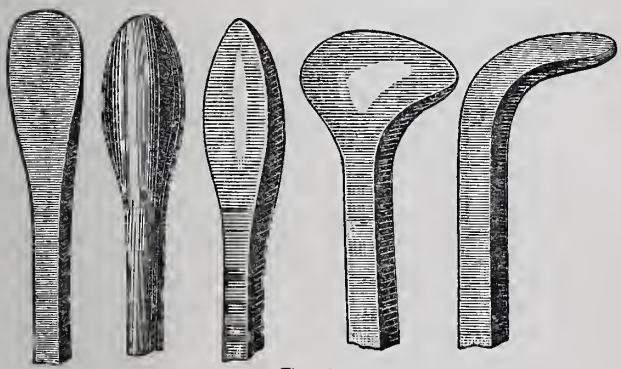


Fig. 63.

As indicated in Fig. 62, *I*, the sheet fits itself only gradually to the chuck, and care must be had that the metal does not wrinkle. For this purpose an entirely flat tool is held with the left hand against the under side of the plate so as to be always opposite to the spinning tool. Without the use of this tool the sheet-metal would soon become wrinkled; but when partially spun the use of the second tool may be dispensed with. All metals cannot be spun with equal facility, copper spinning best, next zinc, tombac and brass. German silver and tin-plate are difficult to spin. To avoid friction between the tool and metal-plate both are kept lubricated with tallow or soap-water. In spinning the metals become gradually

hard, zinc, for instance, becoming so hard in a short time that for articles of any size it can only be spun warm. Warming is effected by holding a spirit-lamp under the article. When the articles have become hard and brittle by spinning they have to be annealed before they can be further spun. By spinning the molecules have assumed an abnormal position and are in a state of tension. If now the half-finished articles were directly heated they would frequently become full of cracks. To avoid this the tension is relieved by pounding the article with a wooden hammer upon a wooden support. The small dents made thereby can readily be removed in finishing the spinning. The articles are first warmed by placing them upon glowing coals and only covered with coals when thoroughly heated through. In large establishments muffle furnaces are also used for annealing. German silver sheet cracking readily, great care is required in annealing it.

For flat articles with bright inner surfaces the chuck shown in *II*, Fig. 62, is used; in this case the plate of sheet-metal *A A* must be somewhat larger than the chuck. After being placed upon the chuck it is covered with a round wooden plate *V*. This wooden plate has in the centre a brass plate with a conical depression, in which sits the back-centre *R*. When the sliding-puppet of the lathe has been brought as close as possible to the chuck, in consequence of the friction the wooden plate and the disk of sheet-metal are also revolved by the revolution of the chuck. The projecting edge of the disk of sheet-metal is then turned so far around the edge of the chuck that it will hold the disk when the wooden plate *V* is removed. It is still better to press the edge of the disk of sheet-metal into a groove in the chuck. By now removing the sliding-puppet and the wooden plate *V*, the disk of sheet-metal is drawn over the hollow chuck like a drum-head. With the assistance of the tools the sheet-metal is now pressed against the side of the chuck by working from the edge towards the centre. The operation being finished, the edge is cut off with a tool.

Articles which are to be smooth inside and outside are also spun without binding screw upon chucks of the above description.

They are first spun over a chuck and then brought into a hollow chuck.

For the manufacture of hollow articles of jewelry from gold-sheet which is too thin for direct working, a gold tube is frequently enveloped inside and outside with silver, then filled with brass and subjected to the required manipulations. The article being finished, the brass core is dissolved in a mixture of acids which does not attack the silver, and finally the outer layer of silver is removed with nitric acid.

To Cut Sheet-brass by Chemical Means.—By drawing a line with solution of mercury salt upon a sheet of brass, the latter on the place where the line is drawn immediately becomes as fragile as glass. The mercury salt is decomposed by the acid dissolving with great rapidity the copper and the mercury combining with the zinc to an amalgam.

To Roughen Sheet-brass for painting with oil paint the following process, which imparts to the sheet a moiré-like appearance, may be recommended. Place the brass for 12 hours in a pickle of concentrated sulphuric acid, 8 parts; concentrated hydrochloric acid, 1; and water, 8; then rinse off with water. This graining may be hastened by using a mixture of potassium bichromate and hydrochloric acid, as well as by the use of a galvanic battery.

To Cut Out Iron Plates with the Assistance of Sulphuric Acid.—A mixture of 1 part by weight of sulphuric acid and 6 of water dissolves steel and iron. Now, by coating an iron or steel plate with a thin layer of wax, drawing any design desired in the wax and placing the plate in the above-mentioned fluid for several hours, the portions constituting the design will drop out. Letters, names and ornaments upon sword blades, etc., are etched in this manner.

To Make a Hole in Hard Steel.—Prepare a mixture of sulphate of copper, 1 oz.; alum, ¼ oz.; powdered common salt, half a teaspoonful; vinegar, 1 gill; and nitric acid, 20 drops. This will make the hole, or, if washed off quickly, will give a beautiful frosted appearance to the metal.

To Detach Gold from Gilt Metallic Articles.—Apply to the

articles a concentrated solution of sal-ammonic in vinegar and heat to a dark-red heat; then throw them into cold, very dilute sulphuric acid, whereby the gold becomes detached in thin scales. The latter are fused with saltpetre and borax, whereby the gold is obtained in a coherent form.

To Give Metals—Lead, Tin, Zinc, etc.—the Capacity of Firmly Adhering to Other Metals, and to Amalgamate with them.—For this purpose sal-ammoniac, phosphorus and borax are added to the metals when in a melted state. To prevent as much as possible the oxidation of the fused metal and the volatilization of the above-mentioned agents, the surface is covered with pulverized wood or animal charcoal.

To Keep Steel from Rusting.—Brush the steel with a solution of paraffine in benzine. This is transparent, and does not disfigure the work as does tallow or white-lead.

To Prevent Metals from Rusting.—The following is said to be a good application to prevent the rusting of metals: Melt 1 oz. of resin in a gill of linseed oil, and while hot mix with it 2 quarts of kerosene oil. This can be kept ready to apply at any time with a brush or rag to any tools or implements required to lay by for a time, preventing any rust, and saving much vexation when the tool is to be used again.

To Prevent Rusting In of Screws.—In machines exposed to heat or moist air the screws soon rust in, even with the use of oil, which later on renders it difficult to take the machines apart. By dipping the screws before use in a thin paste of graphite and oil, they can be readily taken out even after years.

To Loosen Rusted Screws.—One of the simplest and readiest ways of loosening a rusted screw is to apply heat to the head of the screw. A small bar or rod of iron, flat at the end, if reddened in the fire and applied for 2 or 3 minutes to the head of the rusty screw will, as soon as it heats the screw, render its withdrawal as easy by the screw-driver as if the screw had been only recently inserted.

To Prepare Good Crucibles.—Excellent and refractory crucibles and retorts can be prepared from a mixture of 2 parts of pipe-clay

and 1 of quartz sand; the latter must, however, be of sufficient fineness to pass through the eye of a large needle. Crucibles prepared according to this direction withstand the strongest fire of a wind-furnace.

To Purify Gold in the Dry Way (by Cementation), According to Philipp.—Make an intimate mixture of brick-dust, 3 parts; sea salt, 1; alum, 1; and green vitriol, 1, the salts being thoroughly dried before being mixed with the brick-dust. The mixture is then formed with a little wine vinegar to a paste, in the midst of which the gold to be purified is placed; if the gold is in several pieces, the latter are distributed throughout the mass. Gold of from 8 to 12 carats is best adapted for this mode of dry parting. Finer gold must first be alloyed with copper until it shows the above-mentioned carat. With gold alloys of less than 8 carats, the particles of gold are difficult to separate from the cement after cementation. Cementation is effected in a crucible at a moderate red heat. After cooling the porous, chemically pure gold is freed from the cement by means of boiling water and finally melted with borax to a dense mass.

To Repair Cracked Church Bells.—The process of repairing a cracked church bell so that its tone will be completely restored consists in placing a furnace in the interior of the bell so as to heat and fuse the edges of the crack, and pouring new bell-metal in the crack. To prevent the escape of liquid metal the wall of the bell must be provided with suitable contrivances.

To Restore Burnt Cast-steel.—For this purpose a powder is used which consists of saltpetre, 8 parts; colophony, 4; and dragon's blood, 1. Heat the article to a dark-red heat and dust it with the above-mentioned finely pulverized mixture. When the powder is absorbed the article is thoroughly worked upon the anvil. A brown, uniform mixture obtained by fusing together colophony, 3 parts, and boiled linseed oil, 2, is also highly recommended for the purpose. By dipping the red-hot burnt steel into this mass, and repeating the operation it is completely restored. According to another method the burnt steel is heated to a red heat and dusted with a mixture of 8 parts of red chromate of potassium, 4 of salt-

petre, ½ each of aloes and gum arabic, and ¼ of resin. Then heat the article several times and cool it. If the article is to be especially hard take 8 parts of saltpetre and 3 of resin.

To Restore Burnt Steel Tools.—Melt together 1 lb. of tallow and 4 ozs. of black pitch, and then add, with constant stirring, 13 ozs. of sal-ammoniac, 4 ozs. of yellow prussiate of potash, 12 drachms of soap and a handful of common salt. The red-hot articles are plunged into the mass, allowed to cool therein, and then again hardened in the usual manner. For large tools the heating and plunging into the mass must be repeated. Another mixture which may be recommended for the purpose consists of resin, 10 parts; fish oil, 5; tallow, 2; assafœtida, ¼.

To Sharpen Files.—Dull files may be sharpened without recutting by treating them with acid or with the sand blast.

In treating files with acid they are first freed from adhering grease by scratch-brushing with the use of potash or soda lye. They are then brought into an oblong box of a material not attacked by acids, a few thin glass rods or varnished sticks of wood being first placed upon the bottom. The files being laid alongside each other, sufficient cold water to cover them is poured into the box, the eighth part of concentrated nitric acid is then added, and after mixing water and acid by moving the box, the whole is allowed to stand quietly for 25 minutes. The files are then taken from the bath, thoroughly scratch-brushed with the use of water and replaced in the box for 25 minutes, the bath having previously been strengthened by an additional eighth part of nitric acid. During this operation care must be had to several times turn the files and to see that they are entirely covered with the fluid. The files are then again taken from the bath, thoroughly cleansed with a scratch-brush and replaced in the bath, to which previously the sixteenth part of concentrated sulphuric acid has been added. The bath now becomes heated, and red-brown vapors of hyponitric acid escape. Care must be had to keep the box in a rocking motion so that the acids act as uniformly as possible. After 5 minutes the files are again taken out, cleansed, and then replaced for 5 minutes more in the same bath, previously strengthened by

the addition of one-sixteenth part more of concentrated sulphuric acid; care must be had to constantly keep the bath in an undulatory motion. The operation is now finished, the files being finally scratched-brushed, and, for the removal of every trace of acid, placed in a vessel with water compounded with a few handfuls of caustic lime, which gives them a good color. They are then rinsed in clean water, dried over a spirit-flame and rubbed with a little oil.

The treatment with acid may also be effected by means of a galvanic battery, the bath, which is composed of water, 100 parts; nitric acid, 80; and sulphuric, 40, being connected with the positive pole. The negative pole is formed of a copper spiral passing around the files without touching them, and with the end pointing towards the surface of the fluid. By using a galvanic battery of 12 Bunsen elements 10 minutes suffice for the treatment.

The Process of Sharpening Files with the Sand Blast consists in forcing with great rapidity a jet of fine sand against the file to be sharpened by means of a jet of steam. The file is presented to the jet of sand at an angle of from 40° to 50°, and so moved that the jet of sand gradually strikes the entire surface. The sand used for the purpose must be very fine and sharp, and prepared by washing and elutriating. It is used in the shape of a fine mud kept in a suitable holder.

Regarding newly cut and hardened files the following process may be mentioned, whereby the breaking out of the teeth is as much as possible prevented: Fill an iron boiler 30 to 40 inches long, 6 to 8 inches wide and of a corresponding depth with well water. Heat the contents of the boiler to boiling over a large wood-fire which, however, should strike only the bottom of the boiler. Now add to the water 8 ozs. of white soap, previously dissolved in warm water, and 4 ozs. of potash. Then pour in colza oil until the entire surface of the contents of the boiler is covered. The hardened and cleansed files, secured to suitable double iron wires, are then immersed in the boiling fluid for 2 or 3 minutes, when they are taken out and laid upon a table or a board. By the heat communicated to the files the water soon evaporates, whilst the oil

in a short time penetrates through the cuts. By this means the teeth become more elastic and do not break so readily.

To Sharpen Tools.—Instead of oil, which thickens and smears the stone, a mixture of glycerin is recommended. The proportions of the composition vary according to the class of tools to be sharpened. One with a relatively large surface is best sharpened with a clear fluid, 3 parts of glycerin being mixed with 1 of spirits. A graver having a small cutting surface only requires a small pressure on the stone, and in such cases the glycerin should be mixed with only 2 or 3 drops of spirits.

New Method of Securing Flues.—It is the usual method in order to secure a flue in a boiler to expand the end of the flue into a flange, through which rivets are passed to secure it to the plate of the boiler. It is obvious, however, that in thus forming a flange on the end of the flue the metal will be reduced in thickness, and this flanging can be practically done only for purposes where a small or narrow flange will suffice. It is, however, desirable in many cases where flues or tubes or pipes are used, to employ forms thereof having flanges much wider in lateral extent than would be possible to forge or expand from the body of the tube without reducing the stock to such an extent that the flange would not have the requisite strength compared with the body of the tube. Thus with boiler or furnace pipes it is desirable to form integral with the body of the flue the bead or plate that is to form a part of it or is to connect it with the fire chamber or boiler shell. In an invention recently patented, the plate forming the head is formed with a circular flange, which is welded to the flue with which it forms an integral part. In carrying out this method the central portion of the head-plate is first cut out so as to form an opening somewhat smaller than the flue. The edge of the opening is thus bent up by passing a forging at right angles to the body of the plate. If necessary, two flanged openings can be formed in the plate. The head thus prepared is then welded to the flue. It is claimed that the flanged or headed flue thus produced is a much stronger structure than the flue heretofore produced, and has the same lateral extent of flange or head, and it obviates all the objec-

tions incident to structures of similar shape, but having their parts riveted together.

Solidification of Powdered Metals.—According to W. Spring, the degree of pressure required to unite the powders of the respective metals to a solid mass is as follows:

Lead,	unites	at	a	pressure	of	13	tons	to	the square inch.
Tin,	"	"	"	"	19	"	"	"	"
Zinc,	"	"	"	"	38	"	"	"	"
Antimony,	"	"	"	"	38	"	"	"	"
Aluminium,	"	"	"	"	38	"	"	"	"
Bismuth,	"	"	"	"	38	"	"	"	"
Copper,	"	"	"	"	33	"	"	"	"

Lead becomes liquid with a pressure of 33 tons to the square inch, and tin with one of 47 tons.

Combustibility of Iron.—Combustibility is not generally considered one of the properties of iron, yet that metal will, under proper conditions, burn readily. The late Prof. Magnus, of Berlin, Germany, devised the following method of showing the combustibility of iron: A mass of iron filings is approached by a magnet of considerable power, and a quantity thereof is permitted to adhere to it. This loose, spongy tuft of iron powder contains a large quantity of air imprisoned between the particles, and is, therefore, and because of its extremely comminuted condition, well adapted to manifest its combustibility. The flame of an ordinary spirit-lamp or Bunsen burner readily sets fire to the finely divided iron, which continues to burn brilliantly and freely. By waving the magnet to and fro the showers of sparks sent off produce a striking and brilliant effect.

The assertion that iron is more combustible than gunpowder has its origin in the following experiment, which is also a very striking one: A little alcohol is poured into a saucer and ignited. A mixture of gunpowder and iron filings is allowed to fall in small quantities at a time into the flame of the burning alcohol, when it will be observed that the iron will take fire in its passage through the flame, while the gunpowder will fall through it and collect

beneath the liquid alcohol unconsumed. This, however, is a scientific trick, and the experiment hardly justifies the sweeping assertion that iron is more combustible than gunpowder. The ignition of the iron under the foregoing circumstances is due to the fact that the metal particles, being admirable conductors of heat, are able to absorb sufficient heat during their passage through the flame—brief as it is—and they are consequently raised to the ignition point. The particles of the gunpowder, however, are very poor conductors of heat, comparatively speaking, and during the exceedingly brief time consumed in their passage through the flame they do not become heated appreciably, or certainly not to their point of ignition. Under ordinary circumstances, gunpowder is vastly more inflammable than iron.

Another method of exhibiting the combustibility of iron, which would appear to justify the assertion that it is really more combustible than gunpowder, is as follows: Place in a refractory tube of Bohemian glass a quantity of dry, freshly precipitated hydrated ferric oxide. Heat this oxide to bright redness and pass a current of hydrogen through the tube. The hydrogen will deprive the oxide of its oxygen and reduce the mass to the metallic state. If, when the reduction appears to be finished, the tube is removed from the flame and its contents permitted to fall out into the air, it will take fire spontaneously and burn to oxide again. This experiment indicates that pure iron in a state of the extremest subdivision is one of the most combustible substances known, more so even than gunpowder and other explosive substances, which require the application of considerable heat or of a spark to ignite them.

Colors Expressing High Temperatures.

Faint red	960°F	Orange	2010°F
Dull red	1290	Bright orange	2190
Brilliant red	1470	White heat	2370
Cherry red	1650	Bright white heat	2550
Bright cherry red	1830		

Rails and Fastenings per Mile of Railroad.

RAILS PER MILE.

Weight per yd.	Gross Tons per mile.	Weight per yd.	Gross Tons per mile.
65-lb.	102.14	25-lb.	39.29
60 "	94.30	20 "	31.43
56 "	88.00	18 "	28.27
50 "	78.57	16 "	25.14
45 "	70.71	14 "	22.00
40 "	62.86	12 "	18.85
35 "	55.00	10 "	15.71
30 "	47.14	8 "	12.59

FASTENINGS PER MILE.

Length of Rail.	No. of Joints.	No. Splices	No. Bolts.	No. Spikes.
30 feet	352	704	1,408	11,264
28 "	377	754	1,508	11,314
26 "	406	812	1,624	11,372
24 "	440	880	1,760	11,440
22 "	480	960	1,920	11,520
21 "	503	1,006	2,012	11,568
20 "	528	1,056	2,112	11,616
18 "	587	1,174	2,348	11,740

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